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ABSTRACT

Quantitative analysis of scientific literature and especially citation networks have been used to illuminate many aspects of science and research. These studies, formally called statistical bibliography, are now described by the term bibliometrics. This paper provides a survey of bibliometrics including a set of necessary definitions, the scope and structure of bibliometric studies, and a cursory review of some seminal papers. Some suggestions for future research are presented, and a bibliography is attached. (JVP)

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AN OUTLINE OF BIBLIOMETRICS AND CITATION ANALYSIS

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1. Introduktion

The result of scientific research is new knowledge, sometimes in the form of new problems and questions. This new knowledge is manifest only in the scientific literature, which also is one of the channels for dissemination. Derek de Solla Price has in a paper on the structure of publications in science and technology (1), somewhat provocatively, suggested:

"I therefore propose, as a formal definition, to take as science that which is published in scientific papers. We may define these in turn, either crudely as articles in journals in the "World List of Scientific Periodicals", or more artfully by making use of the knitted research front structure. We may suppose quite reasonably (and the evidence bears it out) that the structure is what makes science different from the non-scientific scholarship that is published in other periodicals that are probably not in the "World List". Along the same line of definition we shall define a scientist as a man who sometime in his life has helped in the writing of such a paper."

The difference between a scientist and a technologist was aphoristically stated thus: *"The scientist wants to write but not read, the technologist wants to read but not write."* In line with the definitions above he defined technology as *"that research where the main product is not a paper, but instead a machine, a drug, a product or a process of some sort."*

The basis for the statements above is the fact that a scientific paper has a number of formal characteristics such as a relatively standarized structure (e.g. introduction, method, instrumentation, test/experiment, results, discussion), a special kind of prose with

long sentences in passive voice, using nouns instead of verbs and with multiple adjectives, and the prevalence of references (in a more or less normalized form) to earlier scientific literature.

The use, or non-use, of references in a paper is often taken as an indication of its scientific value and has even been used as a criterion on the "scientificity" in legal disputes.

The references, that tie together the papers of scientific literature into networks, perform several different functions and can be used for a large number of purposes. Quantitative analyses of scientific literature and especially citation networks have been used to illuminate many aspects of science and research. Studies of this type, formerly called "statistical bibliography", are now described by the term "bibliometrics".

The purpose of this paper is to provide a survey of bibliometrics. After some necessary definitions the scope and structure of bibliometric studies is modelled in terms of a set of "dimensions" and their subdivisions. A cursory review of some seminal papers and sketches of the predominant purposes of bibliometric studies provide an overview of bibliometric studies and their results. In conclusion some suggestions for future research are presented.

2. Bibliometrics

Alan Pritchard, who is generally given credit for minting the term "bibliometrics", defines it (2) as follows:

"The definition and purpose of bibliometrics is to shed light on the process of written communications and of the nature and course of a discipline (in so far as this is displayed through written communication) by means of counting and analysing the various facets of written communication."

In the context of this paper the discussions and reviews of bibliometrics will be limited to the studies of the literatures of science. Literary texts, popular literature, the eruditions of humanities and similar writings, are of course also amenable to bibliometric study, (see e.g. (3) and for implicit citation studies (4)), and equally interesting but outside the scope of this review. The literatures on library use and on collection building or weeding in general, on the needs and uses of information in general, on technology or innovation transfer and adaption have neither been considered in this review.

Bibliometric studies of the literatures of science and research can themselves be considered to be part of a larger field of study, sometimes, especially in the USSR, called "scientometrics" (which in its turn in the USSR is considered a subfield of "scientology", in the western countries called "science of science"). Scientometric studies, which are quantitative, often statistical investigations of scientific research as an activity, often provide a basis for evaluation of (or complements to) bibliometric studies.

Bibliometrics in a wider sense (not used in this paper) encompasses the assembly and interpretation of quantitative measures in general of documents or document collections, e.g. size distributions for books or statistics on the use of various fonts. Studies of this

kind, more concerned with documents as objects than as carriers of written communication, fall outside the generally accepted definition of bibliometrics, and would in many cases belong to "analytical bibliography".

3. Definition of terms

The objects of study for bibliometrics are "document units", the term here being taken in the generic sense, encompassing all forms of written records or communications (books, journals, papers, reports etc). Units are chosen according to level of aggregation (e.g. articles or journals) appropriate for the study. The term "document" will be used for brevity although in the case of articles it refers only to a part of the physical document. The physical documents themselves are too comprehensive and difficult to handle in large quantities. The primary working material for bibliometrics is therefore the "document representation", uniquely (hopefully) identifying the physical document. These document representations are usually called (bibliographic) "references" or "citations". In order to avoid conceptual confusion between the references in a document and the document itself and its representation the following conventions will be followed:

Document representation: bibliographic information describing and uniquely identifying a document unit.

Reference: the acknowledgement one document gives (in the form of a document representation) to another.

Citation: the acknowledgement one document receives from another.

(Example: The first acknowledgement in this review of

Price's paper is a reference from this review, but also a citation received by Price's paper).

The formal referencing procedure varies between different publications. The reference in the text can be in the form of a sign or number referring to a footnote or a list of notes at the end, containing the document representation(s), or a name or number referring to a list of document representations at the end of the document. The same document or different parts of the same document can be given as references throughout the document and then the abbreviations op.cit. (opere citato = cited work), idem (= the same), ibid. (ibidem = in the same place) are often used. See (6) for a study of the formal practices of referencing. References are sometimes made not to documents but to personal contacts and communications, in (7) this type of informal referencing is discussed.

4. Sources of data for bibliometric studies

Any bibliometric study is focussed on a set or collection of document representations. The collection can in some instances be an existing aggregation (e.g. a bibliography, an abstracting and indexing service or a library catalog), and might in other cases need to be compiled from various sources, such as other collections or a set of documents. In some cases the collections are so large that sampling procedures must be applied.

Care has not, however, always been taken to properly define and delimit the collection to be studied with respect to the various aspects discussed below, and to ensure that it is representative for the purpose of the study.

The completely dominating sources of data for bibliometric studies are the "Science Citation Index" (abbreviated SCI) and the "Social Science Citation Index" (SSCI), published since 1961 and 1969 respectively by the Institute for Scientific Information (ISI). An "Art and Humanities Citation Index" (A&HCI) was introduced in 1978.

The citation indexes provide a list of documents that have been given as references in one of the "source" journals covered by the respective index. For every document that has received a citation there is an indication of which document provided the reference. The cited documents are ordered alphabetically by the first author's name, and it is thus very easy to count the frequencies of citations to documents and authors. In tables 1-3 are some statistics on the volumes of SCI and SSCI, taken from (8,9).

Table 4 gives some statistics from SCI on a subject basis. Of particular interest are the variations in references/publication and citation/publication.

Figures 1 and 2 present illustrations of the layout and structure of the "citation index" and "source index" parts of SCI taken from (8). The citation indexes of ISI and their development are described in detail in (10).

In 1973 ISI introduced the "Journal Citation Reports" (JCR), which is made up of three parts. The first part identifies the 1 000 journals most frequently cited during the period covered by each JCR. The second part provides for each of the 1 000 journals a detailed listing of all journals by which it was cited and the third part shows which journals each of the 1 000 journals have cited.

SCIENCE CITATION INDEX® 1961-1976
COMPARATIVE STATISTICAL SUMMARY

	1961	1962	1963	1964	1965	1966	1967	1968
Source Journals	613	605	610	700	1,146	1,573	1,711	1,968
Source Journal Issues	5,031	5,595	5,505	5,497	9,432	12,444	13,815	15,911
Anonymous Source Journal Items	3,360	4,047	4,101	9,500	14,500	13,161	15,033	8,095
Authored Source Journal Items	109,958	119,553	125,047	142,139	221,301	260,709	289,066	300,441
Total Source Journal Items	113,318	123,600	129,148	151,639	235,801	273,870	304,099	308,536
Citations to Authored Items*	1,349,800	1,457,862	1,531,200	1,742,896	2,663,806	3,014,737	3,319,546	3,626,027
Citations to Anonymous Items	20,200	21,299	22,204	35,282	52,894	48,443	53,149	57,118
Citations to Patents		6,474	5,396	285,621	208,240	10,826	14,444	15,570
Total Citations from Source Journal Items	1,370,000	1,485,635	1,558,800	1,789,753	2,924,940	3,074,006	3,387,139	3,698,715
Unique Cited Authors*	258,000	266,641	281,296	323,889	438,915	473,658	510,113	546,567
Average Citations per Cited-Author	5.23	5.47	5.44	5.38	6.07	6.36	6.51	6.64
Unique Authored Items Cited*	890,000	894,760	970,216	1,092,384	1,616,987	1,820,877	1,994,120	2,138,526
Citations per Authored Items Cited	1.52	1.63	1.58	1.60	1.65	1.65	1.66	1.70

	1969	1970	1971	1972	1973	1974	1975	1976
Source Journals	2,180	2,192	2,277	2,425	2,364	2,443	2,540	2,717
Source Journal Issues	17,761	17,992	18,976	19,384	20,493	20,719	21,390	22,697
Anonymous Source Journal Items	13,033	11,320	9,639	10,191	9,806	8,096	7,284	6,405
Authored Source Journal Items	328,397	350,555	354,851	367,423	397,137	392,875	411,617	438,146
Total Source Journal Items	341,430	361,875	364,490	377,614	406,943	400,971	418,903	450,956
Citations to Authored Items*	3,777,272	4,041,165	4,302,985	4,579,183	4,938,132	5,148,630	5,446,889	6,080,275
Citations to Anonymous Items	56,958	55,357	61,037	62,884	61,989	65,265	70,332	74,208
Citations to Patents	15,485	11,425	15,783	17,048	17,299	17,815	18,747	22,070
Total Citations from Source Journal Items	3,849,715	4,107,947	4,379,705	4,659,115	5,017,420	5,231,710	5,535,968	6,176,553
Unique Cited Authors*	601,410	619,872	645,505	688,320	710,992	730,001	772,500	812,974
Average Citations per Cited-Author	6.28	6.52	6.67	6.65	6.95	7.05	7.05	7.48
Unique Authored Items Cited*	2,261,839	2,340,128	2,449,573	2,596,663	2,729,968	2,817,833	3,005,712	3,245,632
Citations per Authored Items Cited	1.67	1.73	1.76	1.76	1.81	1.83	1.81	1.87

Table 1, from (8)

SCIENCE CITATION INDEX® 1961-1976
CHRONOLOGICAL DISTRIBUTION OF CITATIONS TO AUTHORED ITEMS (NON-PATENTS)

Percentage of Unique Citations

Reference Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1976																2.35
1975															2.41	8.13
1974														2.54	8.73	9.61
1973													2.63	9.14	10.15	8.98
1972												2.77	8.95	10.23	9.09	7.90
1971											3.13	9.13	10.13	8.93	7.78	6.80
1970										3.20	9.22	10.26	9.13	7.77	6.79	5.96
1969									3.63	9.69	10.20	9.25	7.94	6.77	5.93	5.21
1968								3.38	9.95	10.40	9.27	8.04	6.89	5.93	5.21	4.60
1967							3.39	10.34	10.76	9.18	8.04	6.94	6.00	5.18	4.55	4.08
1966						3.31	10.50	10.90	9.30	7.78	6.69	5.46	5.06	4.39	3.89	3.48
1965					5.07	10.79	11.21	9.76	8.10	6.84	5.96	5.21	4.50	3.94	3.51	3.14
1964				5.36	11.05	11.24	9.68	8.18	6.77	5.76	5.06	4.43	3.83	3.37	3.01	2.71
1963			3.92	11.50	11.34	9.55	8.16	6.90	5.68	4.94	4.32	3.81	3.33	2.92	2.61	2.36
1962		3.86	9.98	11.04	9.10	8.00	6.79	5.82	4.78	4.23	3.71	3.28	2.87	2.52	2.24	2.04
1961	3.51	10.27	10.07	8.78	7.50	6.62	5.74	4.92	4.06	3.62	3.17	2.84	2.48	2.19	1.97	1.79
1960	11.58	10.88	8.90	7.40	6.54	5.85	5.09	4.41	3.68	3.28	2.90	2.60	2.26	2.01	1.80	1.64
1959	12.20	8.90	7.16	5.95	5.41	4.82	4.16	3.65	3.07	2.78	2.39	2.15	1.88	1.66	1.51	1.38
1958	10.01	7.31	6.02	5.00	4.53	4.11	3.58	3.14	2.66	2.39	2.12	1.90	1.67	1.48	1.34	1.22
1957	8.16	6.13	5.12	4.21	3.89	3.52	3.10	2.74	2.33	2.09	1.84	1.66	1.47	1.31	1.19	1.08
1956	6.88	5.26	4.39	3.64	3.39	3.12	2.75	2.43	2.04	1.86	1.66	1.50	1.32	1.18	1.07	0.98
1955	5.82	4.60	3.90	3.26	3.02	2.79	2.44	2.16	1.82	1.66	1.49	1.34	1.19	1.06	0.95	0.89
1954	4.85	3.91	3.35	2.78	2.57	2.41	2.12	1.87	1.61	1.46	1.30	1.18	1.03	0.93	0.84	0.79
1953	4.25	3.46	2.97	2.47	2.27	2.12	1.87	1.67	1.43	1.33	1.19	1.06	0.95	0.84	0.77	0.72
1952	3.56	2.98	2.58	2.11	2.00	1.88	1.64	1.45	1.25	1.15	1.04	0.92	0.84	0.75	0.68	0.63
1951	3.12	2.59	2.23	1.85	1.74	1.64	1.45	1.30	1.12	1.01	0.93	0.83	0.74	0.67	0.61	0.57
1950	2.66	2.29	1.98	1.67	1.54	1.47	1.29	1.17	1.00	0.91	0.84	0.75	0.66	0.60	0.56	0.51

Cumulative Percentage of Unique Citations

Reference Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1976																2.35
1975															2.41	10.48
1974														2.54	11.14	20.09
1973													2.63	11.68	21.29	29.07
1972												2.77	11.58	21.91	30.38	36.97
1971											3.13	11.90	21.71	30.84	38.16	43.77
1970										3.20	12.35	22.16	30.84	38.61	44.95	49.73
1969									3.63	12.89	22.55	31.41	38.78	45.38	50.88	54.94
1968								3.38	13.58	23.29	31.82	39.45	45.67	51.31	56.09	59.54
1967							3.39	13.72	24.34	32.47	39.86	46.39	51.67	56.49	60.64	63.62
1966						3.31	13.89	24.62	33.64	40.25	46.55	52.25	56.73	60.88	64.53	67.10
1965					5.07	14.10	25.10	34.38	41.74	47.09	52.51	57.46	61.23	64.82	68.04	70.24
1964				5.36	18.12	25.34	34.78	42.56	48.51	52.85	57.57	61.89	65.06	68.19	71.05	72.95
1963			3.92	18.86	29.46	34.89	42.94	49.46	54.19	57.79	61.89	65.70	68.39	71.11	73.66	75.31
1962		3.86	13.90	29.90	38.56	42.89	49.73	55.28	58.97	62.02	65.60	68.98	71.26	73.63	75.90	77.35
1961	3.51	14.13	23.97	38.68	46.06	49.51	55.47	60.20	63.03	65.64	68.77	71.82	73.74	75.82	77.87	79.14
1960	15.09	25.01	32.87	46.08	52.60	55.36	60.56	64.61	66.71	68.92	71.67	74.42	76.00	77.83	79.67	80.78
1959	27.29	33.91	40.03	52.03	57.01	60.18	64.72	68.26	69.78	71.65	74.06	76.57	77.88	79.49	81.18	82.16
1958	37.30	41.22	46.05	57.03	62.54	64.29	68.30	71.40	72.44	74.04	76.18	78.47	79.55	80.97	82.52	83.38
1957	45.46	47.35	51.17	61.24	66.43	67.81	71.40	74.14	74.77	76.13	78.02	80.13	81.02	82.28	83.71	84.46
1956	52.34	52.61	55.56	64.88	69.82	70.93	74.15	76.57	76.81	77.99	79.68	81.63	82.34	83.46	84.78	85.73
1955	58.16	57.21	59.46	68.14	72.86	73.72	76.59	78.73	78.63	79.65	81.17	82.97	83.53	84.52	85.73	86.33
1954	63.01	61.12	62.81	70.92	75.41	76.13	78.71	80.60	80.24	81.11	82.47	84.15	84.56	85.45	86.57	87.12
1953	67.26	64.58	65.78	73.39	77.68	78.25	80.58	82.27	81.67	82.44	83.66	85.21	85.51	86.29	87.34	87.84
1952	70.82	67.56	68.36	75.50	79.68	80.13	82.22	83.72	82.92	83.59	84.70	86.13	86.35	87.04	88.02	88.47
1951	73.94	70.15	70.59	77.35	81.42	81.77	83.67	85.02	84.04	84.60	85.63	86.96	87.09	87.71	88.63	89.04
1950	76.60	72.44	72.57	79.02	82.96	83.24	84.96	86.19	85.04	85.51	86.54	87.71	87.75	88.31	89.19	89.55

Percentage of Total Citations

Reference Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1976																1.73
1975															1.81	8.25
1974														1.88	8.82	11.03
1973													1.97	9.23	11.37	10.17
1972												2.14	9.14	11.51	10.21	8.84
1971											2.44	9.38	11.35	9.99	8.65	7.43
1970										2.47	9.48	11.40	10.03	8.52	7.33	6.32
1969									2.98	9.90	11.37	10.13	8.68	7.32	6.29	5.45
1968								2.67	10.38	11.58	10.20	8.71	7.45	6.35	5.46	4.75
1967							2.75	10.60	11.82	10.17	8.74	7.44	6.43	5.48	4.72	4.15
1966						2.65	10.90	12.05	10.05	8.49	7.20	6.19	5.35	4.52	3.95	3.48
1965					4.14	11.50	12.26	10.59	8.64	7.33	7.27	5.42	4.70	4.06	3.55	3.13
1964				4.55	13.60	12.45	10.58	8.82	7.22	6.14	5.30	4.58	3.97	3.44	3.00	2.67
1963			3.36	14.15	12.50	10.41	8.83	7.38	6.05	5.19	4.49	3.90	3.40	2.94	2.58	2.29
1962		3.28	11.26	12.39	10.12	8.55	7.17	6.06	4.99	4.34	3.79	3.30	2.88	2.50	2.18	1.94
1961	4.14	11.38	11.82	9.70	8.06	7.00	5.95	5.05	4.16	3.66	3.16	2.79	2.44	2.13	1.87	1.67
1960	10.90	12.28	10.11	8.00	6.88	6.05	5.22	4.50	3.73	3.29	2.86	2.54	2.20	1.92	1.71	1.52
1959	11.07	9.83	8.01	6.34	5.60	4.94	4.20	3.64	3.04	2.68	2.32	2.06	1.81	1.58	1.42	1.27
1958	9.14	8.01	6.62	5.29	4.69	4.20	3.61	3.13	2.65	2.36	2.07	1.84	1.61	1.42	1.27	1.13
1957	7.51	6.66	5.63	4.44	4.01	3.61	3.13	2.75	2.34	2.08	1.81	1.62	1.43	1.27	1.12	1.01
1956	6.63	5.65	4.77	3.81	3.46	3.16	2.73	2.41	2.03	1.83	1.62	1.45	1.28	1.14	1.01	0.92
1955	5.57	4.78	4.13	3.35	3.04	2.77	2.40	2.12	1.80	1.62	1.43	1.28	1.13	1.00	0.89	0.81
1954	4.74	4.01	3.46	2.78	2.52	2.31	2.03	1.79	1.53	1.38	1.22	1.09	0.96	0.85	0.77	0.70
1953	4.16	3.56	3.11	2.48	2.26	2.11	1.83	1.61	1.40	1.29	1.14	1.01	0.91	0.80	0.71	0.65
1952	3.52	3.02	2.67	2.09	1.95	1.85	1.56	1.39	1.19	1.09	0.97	0.86	0.78	0.68	0.61	0.55
1951	3.08	2.62	2.30	1.86	1.70	1.65	1.43	1.28	1.13	1.03	0.96	0.87	0.79	0.74	0.69	0.64
1950	2.66	2.26	1.99	1.67	1.47	1.39	1.22	1.09	0.95	0.86	0.77	0.68	0.61	0.55	0.50	0.45

Cumulative Percentage of Total Citations

Reference Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1976																1.73
1975															1.81	9.98
1974														1.88	10.63	21.00
1973													1.97	11.11	22.00	31.17
1972												2.14	11.11	22.62	32.21	40.01
1971											2.44	11.52	22.46	32.61	40.86	47.44
1970										2.47	11.92	22.92	32.49	41.13	48.19	53.76
1969									2.98	12.37	23.29	33.05	41.17	48.45	54.48	59.21
1968								2.67	13.36	23.95	33.49	41.76	48.62	54.80	59.94	63.96
1967							2.75	13.27	25.18	34.12	42.23	49.20	55.05	60.28	64.66	68.11
1966						2.65	13.65	25.32	35.23	41.61	49.43	55.39	60.40	64.85	68.61	71.59
1965					4.14	14.15	25.91	35.71	43.87	49.94	55.70	60.81	65.10	68.91	72.16	74.72
1964				4.55	17.74	26.60	36.49	44.73	51.09	56.08	61.00	65.39	69.07	72.35	75.16	77.39
1963			3.36	18.70	30.24	37.01	45.32	52.11	57.14	61.27	65.49	69.29	72.47	75.29	77.74	79.68
1962		3.28	14.62	31.09	40.36	45.56	52.49	58.17	62.13	65.61	69.28	72.59	75.35	77.79	79.92	81.62
1961	4.14	14.46	26.44	40.79	48.42	52.56	58.44	63.22	66.29	69.27	72.44	75.38	77.79	79.92	81.79	83.29
1960	15.04	26.74	36.55	48.79	55.30	58.61	63.66	67.72	70.02	72.56	75.30	77.92	79.99	81.85	83.50	84.81
1959	26.07	36.57	44.56	55.13	60.90	63.55	67.86	71.36	73.06	75.24	77.62	79.98	81.80	83.43	84.92	86.08
1958	35.21	44.58	51.18	60.42	65.59	67.75	71.47	74.49	75.71	77.60	79.69	81.82	83.41	84.85	86.19	87.21
1957	42.72	51.24	56.81	64.86	69.60	71.36	74.60	77.24	78.05	79.68	81.50	83.44	84.84	86.12	87.31	88.22
1956	49.15	56.89	61.58	68.67	73.06	74.52	77.33	79.65	80.08	81.51	83.12	84.89	86.12	87.26	88.32	89.14
1955	54.72	61.67	65.71	72.02	76.10	77.29	79.73	81.77	81.88	83.13	84.55	86.17	87.25	88.26	89.21	89.95
1954	59.46	65.68	69.17	74.80	78.62	79.60	81.76	83.55	83.41	84.51	85.77	87.26	88.21	89.11	89.98	90.65
1953	63.58	69.24	72.28	77.28	80.88	81.71	83.59	85.17	84.81	85.80	86.91	88.27	89.12	89.91	90.69	91.30
1952	67.10	72.26	74.95	79.37	82.83	83.56	85.15	86.56	86.00	86.89	87.88	89.13	89.90	90.59	91.30	91.85
1951	70.16	74.88	77.25	81.23	84.53	85.21	86.58	87.84	87.13	87.92	88.84	90.00	90.69	91.33	91.99	92.49
1950	72.82	77.14	79.24	82.84	86.00	86.60	87.80	88.93	88.08	88.78	89.61	90.68	91.30	91.88	92.49	92.94

Table 2, from (8)

SOCIAL SCIENCES CITATION INDEX™ 1970-1976
COMPARATIVE STATISTICAL SUMMARY

	1970	1971	1972	1973	1974	1975	1976
Selectively Covered Source Journals	2,275	2,277	1,212	1,158	1,274	1,235	2,520
Fully Covered Source Journals	1,000	1,030	970	1,082	1,278	1,232	1,517
Anonymous Source Journal Items	2,140	2,162	1,998	2,255	2,604	3,433	5,073
Authored Source Journal Items	70,692	77,722	71,152	67,661	80,451	94,755	121,843
Total Source Journal Items	72,832	79,884	73,150	69,916	83,055	98,188	126,916
Citation to Authored Journal and Monograph Items	543,557	578,609	535,382	563,900	781,759	913,369	1,235,547
Citations to Anonymous Items	47,519	42,010	44,909	43,045	62,632	79,750	73,980
Citations to Corporate Author Items	26,949	23,459	23,491	26,493	27,185	32,299	62,747
Total Citations from Source Journal Items	618,025	644,078	603,782	633,438	871,576	1,025,418	1,372,274
Unique Authored Items Cited	423,144	436,094	400,062	414,990	576,361	685,586	925,405
Citations per Authored Items Cited	1.28	1.33	1.34	1.36	1.36	1.33	1.33
Unique Reference Authors Cited	166,470	169,277	158,000	165,170	230,031	253,004	335,738
Average Citations per Cited Author	3.27	3.42	3.39	3.41	3.40	3.61	3.68
Number of Corporate Addresses	66,448	70,965	64,063	62,607	73,943	84,471	112,158
Number of Unique Source Authors	63,225	67,936	63,391	63,450	73,351	82,884	112,530
Average Number of References per Article	8.49	8.06	8.25	9.06	10.5	10.44	10.81

CHRONOLOGICAL DISTRIBUTION OF CITATIONS TO AUTHORED ITEMS

Percentage of Total Citations

	1970	1971	1972	1973	1974	1975	1976
1976							1.46
1975						1.57	7.60
1974					1.55	7.85	9.63
1973				1.90	8.69	10.46	9.09
1972			2.27	8.72	10.54	9.36	8.00
1971		2.32	9.49	10.50	9.12	7.98	6.95
1970	2.61	10.15	10.63	9.16	8.03	7.01	6.18
1969	11.34	10.74	9.14	8.01	6.92	5.99	5.19
1968	11.21	9.28	7.86	7.10	6.02	5.23	4.62
1967	8.83	7.73	6.58	6.03	5.14	4.53	4.05
1966	7.49	6.59	5.63	5.24	4.49	3.92	3.47
1965	6.36	5.74	4.98	4.47	3.90	3.43	3.02
1964	5.30	4.75	4.12	3.75	3.27	2.91	2.58
1963	4.61	4.15	3.59	3.28	2.88	2.51	2.28
1962	3.99	3.61	3.25	2.88	2.56	2.24	2.01
1961	3.34	3.08	2.71	2.42	2.19	1.90	1.74
1960	3.05	2.79	2.49	2.23	1.99	1.75	1.59
1959	2.56	2.28	2.08	1.87	1.68	1.49	1.33
1958	2.34	2.09	1.95	1.73	1.55	1.36	1.26
1957	2.07	1.89	1.67	1.54	1.39	1.23	1.14
1956	1.75	1.65	1.46	1.34	1.22	1.08	.99
1955	1.51	1.36	1.24	1.08	0.97	0.88	.83
1954	1.41	1.28	1.20	1.00	0.97	0.83	.78
1953	1.26	1.16	1.06	0.95	0.88	0.75	.72
1952	1.04	0.93	0.86	0.76	0.72	0.63	.59
1951	.99	0.89	0.84	0.73	0.70	0.62	.59
1950	.94	0.85	0.79	0.71	0.64	0.58	.55

Percentage of Unique Citations

	1970	1971	1972	1973	1974	1975	1976
1976							1.76
1975						1.90	7.99
1974					1.91	8.38	9.67
1973				2.31	9.28	10.47	8.89
1972			2.73	9.34	10.63	9.20	7.74
1971		2.71	9.79	10.68	8.99	7.69	6.64
1970	2.92	10.29	10.59	9.25	7.71	6.66	5.83
1969	11.26	10.57	8.94	7.75	6.54	5.66	4.90
1968	11.06	8.99	7.61	6.71	5.64	4.87	4.34
1967	8.67	7.46	6.31	5.68	4.80	4.24	3.81
1966	7.15	6.15	5.24	4.76	4.12	3.60	3.22
1965	6.11	5.39	4.69	4.16	3.65	3.23	2.87
1964	5.09	4.50	3.86	3.51	3.07	2.76	2.46
1963	4.36	3.92	3.33	3.02	2.69	2.35	2.14
1962	3.72	3.32	2.94	2.59	2.33	2.06	1.88
1961	3.18	2.93	2.57	2.25	2.09	1.82	1.69
1960	2.88	2.62	2.29	2.06	1.87	1.65	1.52
1959	2.44	2.17	1.94	1.72	1.59	1.41	1.29
1958	2.17	1.94	1.76	1.55	1.41	1.27	1.18
1957	1.90	1.74	1.50	1.36	1.27	1.13	1.05
1956	1.63	1.56	1.36	1.26	1.14	1.01	.93
1955	1.49	1.34	1.22	1.07	0.97	0.88	.84
1954	1.33	1.24	1.14	0.95	0.93	0.81	.77
1953	1.20	1.09	1.00	0.89	0.84	0.74	.71
1952	1.05	0.96	0.87	0.78	0.74	0.65	.61
1951	0.97	0.89	0.84	0.73	0.70	0.62	.58
1950	0.91	0.83	0.77	0.68	0.63	0.58	.54

Cumulative Percentage of Total Citations

	1970	1971	1972	1973	1974	1975	1976
1976							1.46
1975						1.57	9.06
1974					1.55	9.42	18.69
1973				1.90	10.24	19.88	27.78
1972			2.27	10.62	20.78	29.24	35.78
1971		2.32	11.76	21.12	29.90	37.22	42.73
1970	2.61	12.47	22.39	30.48	37.93	44.23	48.91
1969	13.95	23.21	31.53	38.49	44.85	50.22	54.10
1968	25.16	32.49	39.39	45.59	50.87	55.45	58.72
1967	33.99	40.22	45.97	51.62	56.01	59.98	62.77
1966	41.48	46.81	51.60	56.86	60.50	63.90	66.24
1965	47.84	52.55	56.58	61.33	64.40	67.33	69.26
1964	53.14	57.30	60.70	65.08	67.67	70.24	71.84
1963	57.75	61.45	64.29	68.36	70.55	72.75	74.12
1962	61.74	65.06	67.71	71.24	73.11	74.99	76.13
1961	65.08	68.14	70.25	73.66	75.30	76.89	77.87
1960	68.13	70.93	72.74	75.89	77.29	78.64	79.46
1959	70.69	73.21	74.82	77.76	78.97	80.13	80.79
1958	73.03	75.30	76.77	79.49	80.52	81.49	82.05
1957	75.10	77.19	78.44	81.03	81.91	82.72	83.19
1956	76.85	78.84	79.90	82.37	83.13	83.80	84.18
1955	78.36	80.20	81.14	83.45	84.10	84.68	85.01
1954	79.77	81.48	82.34	84.45	85.07	85.51	85.79
1953	81.03	82.64	83.40	85.40	85.95	86.26	86.51
1952	82.07	83.57	84.26	86.16	86.67	86.89	87.10
1951	83.06	84.46	85.10	86.89	87.37	87.51	87.69
1950	84.00	85.31	85.89	87.60	88.01	88.09	88.24

Cumulative Percentage of Unique Citations

	1970	1971	1972	1973	1974	1975	1976
1976							1.76
1975						1.90	9.75
1974					1.91	10.28	19.42
1973				2.31	11.19	20.75	28.31
1972			2.73	11.65	21.82	29.95	36.05
1971		2.71	12.52	22.33	30.81	37.64	42.69
1970	2.92	13.00	23.11	31.62	38.52	44.20	48.52
1969	14.18	23.57	32.05	39.37	45.06	49.96	53.42
1968	25.24	32.56	39.66	46.08	50.70	54.81	57.76
1967	33.91	40.02	45.97	51.76	55.50	59.05	61.57
1966	41.06	46.17	51.21	56.52	59.62	62.67	64.79
1965	47.17	51.56	55.90	60.68	63.27	65.90	67.66
1964	52.26	56.06	59.76	64.19	66.34	68.66	70.12
1963	56.62	59.98	63.09	67.21	69.03	71.01	72.26
1962	60.34	63.30	66.03	69.80	71.36	73.07	74.14
1961	63.52	66.23	68.60	72.05	73.45	74.89	75.83
1960	66.40	68.85	70.89	74.11	75.32	76.54	77.35
1959	68.84	71.02	72.83	75.85	76.91	77.95	78.64
1958	71.01	72.96	74.59	77.40	78.32	79.22	79.82
1957	72.91	74.70	76.09	78.76	79.59	80.35	80.87
1956	74.54	76.26	77.45	80.02	80.73	81.36	81.80
1955	76.03	77.60	78.76	81.09	81.70	82.24	82.64
1954	77.36	78.84	79.81	82.04	82.63	83.05	83.41
1953	78.56	79.93	80.81	82.93	83.47	83.79	84.12
1952	79.61	80.89	81.68	83.71	84.21	84.44	84.73
1951	80.58	81.78	82.52	84.44	84.91	85.06	85.31
1950	81.49	82.61	83.29	85.12	85.54	85.64	85.85

Table 3, from (9)

TABLE 4

FIELD AND SUBFIELD PUBLICATION AND REFERENCE COUNTS*
from NARIN (22)

Field	Number of Journals	Number of Publications	Number of References	Number of Citations	Reference/ Publication	Citation/ Publication
Engineering & Technology	428	27718.	161848.	135026.	5.84	4.87
Biomedical Research	275	33211	614051.	564030.	18.48	19.98
Psychology	91	7178.	70171.	63652.	9.78	8.87
Biology	294	22634.	224485.	177253.	9.92	7.83
Mathematics	90	7254	38155.	44472.	5.26	6.13
Earth & Space	115	10042.	120820.	113293.	12.03	11.28
Physics	123	33189.	416410.	464182.	12.55	13.99
Chemistry	186	42265.	588346.	571840.	13.92	13.53
Clinical Medicine	644	74830.	1090663.	974899.	14.58	13.03
All Fields	2246	258341.	3324949.	3208647.	12.80	12.40
Subfield						
Genrl & Internal Med	99	15686.	243900.	262200.	15.55	16.72
Allergy	6	425.	6493.	5521.	15.28	12.99
Anesthesiology	8	914.	13170.	8876.	14.41	9.71
Cancer	17	2607.	47655.	41217.	18.28	15.81
Cardiovascular Systm	23	2459.	46164.	47630.	18.77	19.37
Dentistry	20	1830.	17952.	14097.	9.81	7.70
Dermat & Venerl Dis	11	1303.	17814.	14104.	13.67	10.82
Endocrinology	18	2720.	49510.	52119.	18.20	19.16
Fertility	5	705.	10487.	6856.	14.88	9.72
Gastroenterology	14	1239.	23206.	16691.	18.73	13.47
Geriatrics	10	533.	5881.	2763.	11.03	5.18
Hematology	12	1112.	19276.	18305.	17.33	16.46
Immunology	28	3847.	66772.	63349.	17.36	16.47
Obstetrics & Gynecol	12	1502.	19263.	15624.	12.82	10.40
Neurol & Neurosurg	37	4263.	77006.	61348.	18.06	14.39
Ophthalmology	17	1788.	21152.	17214.	11.83	9.63
Orthopedics	8	1009.	10250.	9398.	10.16	9.31
Arthritis & Rheumat	5	315.	4835.	4404.	15.35	13.98
Otorhinolaryngology	10	980.	10773.	8192.	10.99	8.36
Pathology	21	2178.	38092.	36133.	17.49	16.59
Pediatrics	19	2259.	33950.	28794.	15.03	12.75
Pharmacology	49	5881.	94828.	72164.	16.12	12.27

TABLE 4 (Continued)

FIELD AND SUBFIELD PUBLICATION AND REFERENCE COUNTS*

from NARIN (22)

Subfield	Number of Journals	Number of Publications	Number of References	Number of Citations	Reference/ Publication	Citation/ Publication
Pharmacy	23	3175.	37502.	19083.	11.81	6.01
Psychiatry	32	1541.	15147.	14047.	9.83	9.12
Radiology & Nucl Med	30	3325.	36263.	30849.	10.91	9.28
Respiratory System	8	875.	12067.	8447.	13.79	9.65
Surgery	36	4486.	50629.	49909.	11.29	11.13
Tropical medicine	6	478.	5413.	5616.	11.32	11.75
Urology	7	926.	8919.	7471.	9.63	8.07
Nephrology	2	189.	4592.	827.	24.30	4.38
Veterinary Medicine	23	2232.	23441.	14331.	10.50	6.42
Addictive Diseases	4	203.	2311.	1403.	11.38	6.91
Hygiene & Publ Hlth	19	1494.	12211.	13998.	8.17	9.37
Misc Clinical Med	5	351.	3739.	1919.	10.65	5.47
Physiology	21	2455.	57761.	88905.	23.53	36.21
Anatomy & Morphology	9	603.	11933.	15536.	19.79	25.76
Embryology	8	611.	12667.	6800.	20.73	11.13
Genetics & Heredity	37	2707.	40952.	31586.	15.13	11.67
Nutrition & Dietet	14	1019.	17986.	11752.	17.65	11.53
Biochem & Molec Biol	54	12706.	264531.	322438.	20.82	25.38
Biophysics	12	690.	11642.	5144.	16.87	7.46
Cell Biol Cyt & Hist	30	3208.	68618.	72880.	21.39	22.72
Microbiology	22	3108.	51191.	42386.	16.47	13.64
Virology	7	1406.	25085.	21056.	17.84	14.98
Parasitology	9	916.	10013.	8627.	10.93	9.42
Biomedical Engineering	10	607.	5029.	2701.	8.29	4.45
Microscopy	6	372.	4812.	2577.	12.94	6.93
Misc Biomedical Res	19	1154.	8842.	5045.	7.66	4.37
Genrl Biomedical Res	17	1669.	22989.	26597.	13.77	15.94
General Biology	7	290.	3499.	4389.	12.07	15.13
General Zoology	15	638.	10537.	9544.	16.52	14.96
Entomology	24	2039.	16602.	13671.	8.14	6.70
Miscellaneous Zool	19	1920.	22797.	15163.	11.87	7.90
Marine Bio & Hydrobl	19	1408.	13469.	10411.	9.57	7.39
Botany	74	5864.	70628.	57890.	12.04	9.87
Ecology	19	1041.	10805.	11012.	10.38	10.58
Agricult & Food Sci	93	7131.	53257.	37639.	7.47	5.28
Dairy & Animal Sci	16	1808.	17395.	14180.	9.62	7.84

TABLE 4 (Continued)

FIELD AND SUBFIELD PUBLICATION AND REFERENCE COUNTS*
from NARIN (22)

Subfield	Number of Journals	Number of Publications	Number of References	Number of Citations	Reference/ Publication	Citation/ Publication
Op Res & Managmt Sci	7	446.	1498.	1083.	3.36	2.43
Clinical Psychology	6	566.	4114.	5893.	7.27	10.41
Personality & Soc Ps	10	785.	6167.	5741.	7.86	7.31
Devel & Child Psycho	6	342.	3471.	3123.	10.15	9.13
Experimental Psychol	12	1929.	18130.	19569.	9.40	10.14
General Psychology	29	1583.	17352.	16246.	10.96	10.26
Misc Psychology	16	721.	5620.	3818.	7.79	5.30
Behavioral Science	12	1252.	15317.	9262.	12.23	7.40
Probabity & Statist	18	1242.	6949.	9984.	5.60	8.04
Applied mathematics	21	1389.	7768.	8441.	5.59	6.08
General Mathematics	46	4301.	21698.	24525.	5.04	5.70
Misc Mathematics	5	322.	1740.	1522.	5.40	4.73

*Articles, notes, reviews in 1973 Corporate Tapes of SCI, with multi-field journals omitted, counting only references and journals within the SCI journal set.

In 1968 ISI first published the "International Directory of Research and Development Scientists" (IDR & DC), which provided the addresses to all the authors of papers covered by "Current Contents/Life Sciences" and "Current Contents/Physical Sciences". In 1971 the name was changed to "Who is publishing in Science" (WIPIS). With the change of name there was also an increase in coverage so that the basis is formed by all seven editions of "Current Contents" (a series of publications, also published by ISI, containing reproductions of journal content pages for current awareness purposes).

In table 5 statistics on the number of publishing scientists for each country is reproduced from the 1971 "WIPIS".

In 1977 "WIPIS" provided names and addresses of more than 360 000 authors from about 30 000 institutions in 179 countries.

The products of ISI are thus providing a wealth of data for bibliometric studies, and have also been used extensively.

5. Bibliometric laws

Three basic bibliometric laws or distributions are recognized.

a) Bradford's law describes the distribution of documents (usually journals) in a specific discipline or problem-area. (11,12)

b) Lotka's law describes the distribution of the number of authors of varying productivity. (13)

c) Zipf's law describes word-frequency rankings. (14)

NATION STATES

UNITED STATES	92011
USSR	17209
ENGLAND	16878
GERMANY	13651
FRANCE	10585
CANADA	9206
JAPAN	8473
INDIA	5144
AUSTRALIA	3914
ITALY	3279
SWEDEN	2524
NETHERLANDS	2451
SWITZERLAND	2402
CZECHOSLOVAKIA	2161
SCOTLAND	2066
POLAND	1970
ISRAEL	1787
BELGIUM	1473
HUNGARY	1461
AUSTRIA	1107
DENMARK	1091
NORWAY	856
ROUMANIA	851
NEW ZEALAND	755
FINLAND	731
SOUTH AFRICA	691
WALES	686
SPAIN	517
ARGENTINA	505
BULGARIA	486
YUGOSLAVIA	481
U A R	442
BRAZIL	388
IRELAND	356
NORTH IRELAND	346
CHILE	340
MEXICO	246
NIGERIA	242
GREECE	220
TAIWAN	155
IRAN	145
PAKISTAN	140
VENEZUELA	137
TURKEY	112
MALAYSIA	105
KENYA	100
LEBANON	93
SINGAPORE	92
HONG KONG	90
UGANDA	89
THAILAND	78
JAMAICA	74
COLOMBIA	60
PHILIPPINES	59
SUDAN	58
PORTUGAL	55
GHANA	54
BANGLADESH	53
SENEGAL	53
ALGERIA	52
CEYLON	52
IRAQ	52
RHODESIA	51
TANZANIA	45
NEW GUINEA	43
ZAMBIA	40
KOREA	37
URUGUAY	34
VIETNAM	33
W IND ASSOC ST	33
IVORY COAST	32
MADAGASCAR	32
PERU	32
COSTA RICA	28
TRINIDAD & TOBA	27
GUATEMALA	26
CANAL ZONE	25
CONGO	24
TUNISIA	22
CUBA	21
CAMEROON	20
FIJI ISLANDS	17
ETHIOPIA	16
SIERRA LEONE	16
SAUDI ARABIA	14
INDONESIA	13
MOROCCO	13
ICELAND	12
LIBYA	12
LIECHTENSTEIN	11
PANAMA	11
MALTA	10
KUWAIT	9
CHAD	8
ECUADOR	8
MALAWI	8
AFGHANISTAN	7
BOTSWANA	7
EL SALVADOR	7
NEW CALEDONIA	7
CYPRUS	6
FRENCH W INDIES	6
HONDURAS	6
LIBERIA	6
LUXEMBOURG	6
NEPAL	6
BARBADOS	5
CENT AFR REP	5
GAMBIA	5
GUYANA	5
JORDAN	5
MONACO	5
BOLIVIA	4
BORNEO	4
CAMBODIA	4
NETH ANTILLES	4
SYRIA	4
TAHITI	4
BAHAMAS	3
BURMA	3
DAHOMEY	3
MAURITIUS	3
MOZAMBIQUE	3
SURINAM	3
SWAZILAND	3
ANGOLA	2
BRIT HONDURAS	2
CANARY ISLANDS	2
NICARAGUA	2
PARAGUAY	2
SOLOMON ISLANDS	2
U VOLTA	2
WEST AFRICA	2
ABU DHABI	1
BERMUDA	1
BURUNDI	1
CAROLINE ISLAND	1
DUTCH GUIANA	1
GREENLAND	1
GUINEA	1
LESOTHO	1
MALI	1
MARTINIQUE	1
MONGOLIA	1
REPUB TOGO	1
RWANDA	1
W SAMOA	1
YEMEN	1

U. S. A.

CALIFORNIA	11612
NEW YORK	11097
MASSACHUSETTS	5347
ILLINOIS	5276
PENNSYLVANIA	4855
MARYLAND	3838
OHIO	3633
TEXAS	3587
D C	3454
NEW JERSEY	3397
MICHIGAN	3126
WISCONSIN	1892
FLORIDA	1885
MISSOURI	1806
INDIANA	1803
CONNECTICUT	1727
NORTH CAROLINA	1682
MINNESOTA	1680
COLORADO	1679
WASHINGTON	1660
GEORGIA	1445
VIRGINIA	1439
TENNESSEE	1389
IOWA	1168
LOUISIANA	903
OREGON	839
NEW MEXICO	789
ARIZONA	773
KENTUCKY	762
KANSAS	756
ALABAMA	656
OKLAHOMA	630
UTAH	589
NEBRASKA	441
RHODE ISLAND	411
MISSISSIPPI	401
HAWAII	387
SOUTH CAROLINA	377
DELAWARE	353
WEST VIRGINIA	344
NEW HAMPSHIRE	284
ARKANSAS	243
NORTH DAKOTA	212
MONTANA	208
VERMONT	180
MAINE	177
IDAHO	168
WYOMING	143
SOUTH DAKOTA	138
PUERTO RICO	132
ALASKA	118
NEVADA	113
VIRGIN ISLANDS	7
GUAM	6

U. S. S. R.

RSFSR	12985
UKSSR	2636
BESSR	345
AZSSR	196
UZSSR	177
ARSSR	175
KASSR	159
GESSR	138
MOSSR	103
ESSSR	85
LASSR	82
LISSR	74
TASSR	34
KISSR	14
DASSR	6
TUSSR	6

Geographical sources of published papers listed in the five editions of *Current Contents*® in 1971. The name of each country is followed by the number of papers it produced. Countries are listed in order of number of papers produced. Totals for the U.S.A. and the U.S.S.R. are broken down by states/possessions and republics respectively.

TABLE 5

from "Who is Publishing in Science", 1971

CITATION INDEX

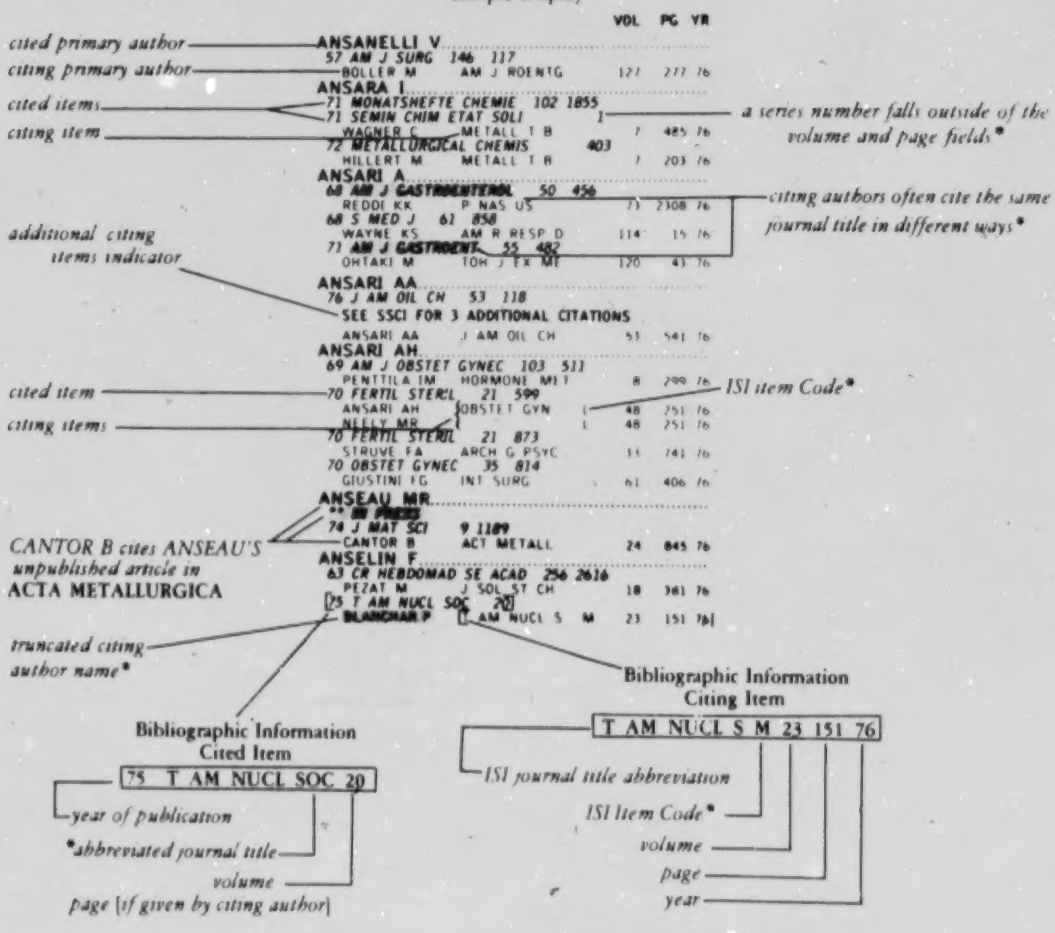
The Citation Index of the *SCI*® is comprised of all the references (cited items) found in *SCI* Source Index items (citing items) during the period covered. It is designed so that, for any cited item (authored or anonymous, published or unpublished) you can see at a glance who was citing it and in what publications it was cited.

The Citation Index is accessed by an alphabetic listing of cited primary authors (ISI® uses the order of presentation to determine primary authorship, i.e., the first author is considered the primary author). Cited anonymous items are found after the alphabetic listing and are accessed by cited publication title.

Under a cited primary author you find the bibliographic description(s) of the cited item(s) connected with that name. The cited item bibliographic description begins with the year of publication followed by the cited publication title, volume number and page number.

Under the cited item bibliographic description the user sees the *citing* primary author along with a bibliographic description of the *citing* item. The *citing* item bibliographic description consists of the standard ISI source journal abbreviation, an ISI item code, volume, beginning page, and ends with the year of publication. If there are also *SSCI*™ source journal items *citing* an item it will be noted directly under the cited item and before the *SCI citing* items.

Sample Display


VOL PG YR
cited primary author
ANSANELLI V
57 AM J SURG 146 117
citing primary author
BOLLER M AM J ROENTG 127 277 76
ANSARA I
cited items
71 MONATSHEFTE CHEMIE 102 1855
71 SEMIN CHIM ETAT SOLI 1
a series number falls outside of the volume and page fields*
citing item
WAGNER C METALL T B 7 425 76
72 METALLURGICAL CHEMIS 403
HILLERT M METALL T B 7 203 76
ANSARI A
68 AM J GASTROENTEROL 50 456
REDDI KK P NAS US 73 2308 76
68 S MED J 61 858
citing authors often cite the same journal title in different ways*
WAYNE KS AM R RESP D 114 15 76
additional citing items indicator
71 AM J GASTROENT 55 482
OHTAKI M TOH J EX ME 120 43 76
ANSARI AA
76 J AM OIL CH 53 118
SEE SSCI FOR 3 ADDITIONAL CITATIONS
ANSARI AA J AM OIL CH 53 541 76
ANSARI AH
69 AM J OBSTET GYNEC 103 511
PENTTILA IM HORMONE MET 8 299 76
cited item
70 FERTIL STERIL 21 599
ISI item Code*
citing items
ANSARI AH OBSTET GYN L 48 251 76
NEELY MR L 48 251 76
70 FERTIL STERIL 21 873
STRUVE FA ARCH G PSYC 31 741 76
70 OBSTET GYNEC 35 814
GIUSTINI FG INT SURG 61 406 76
ANSEAU MR
** IN PRESS
74 J MAT SCI 9 1189
CANTOR B cites ANSEAU'S unpublished article in ACTA METALLURGICA
CANTOR B ACT METALL 24 845 76
ANSELIN F
63 CR HEBDOMAD SE ACAD 256 2616
PEZAT M J SOL ST CH 18 381 76
75 T AM NUCL SOC 20
truncated citing author name*
BLANCHAR P J AM NUCL S M 23 151 76
Bibliographic Information Cited Item
75 T AM NUCL SOC 20
year of publication
*abbreviated journal title
volume
page (if given by citing author)
Bibliographic Information Citing Item
T AM NUCL S M 23 151 76
ISI journal title abbreviation
ISI Item Code*
volume
page
year

*See SCI Codes and Conventions for further information

Figure 1, from "Science Citation Index"

SOURCE INDEX

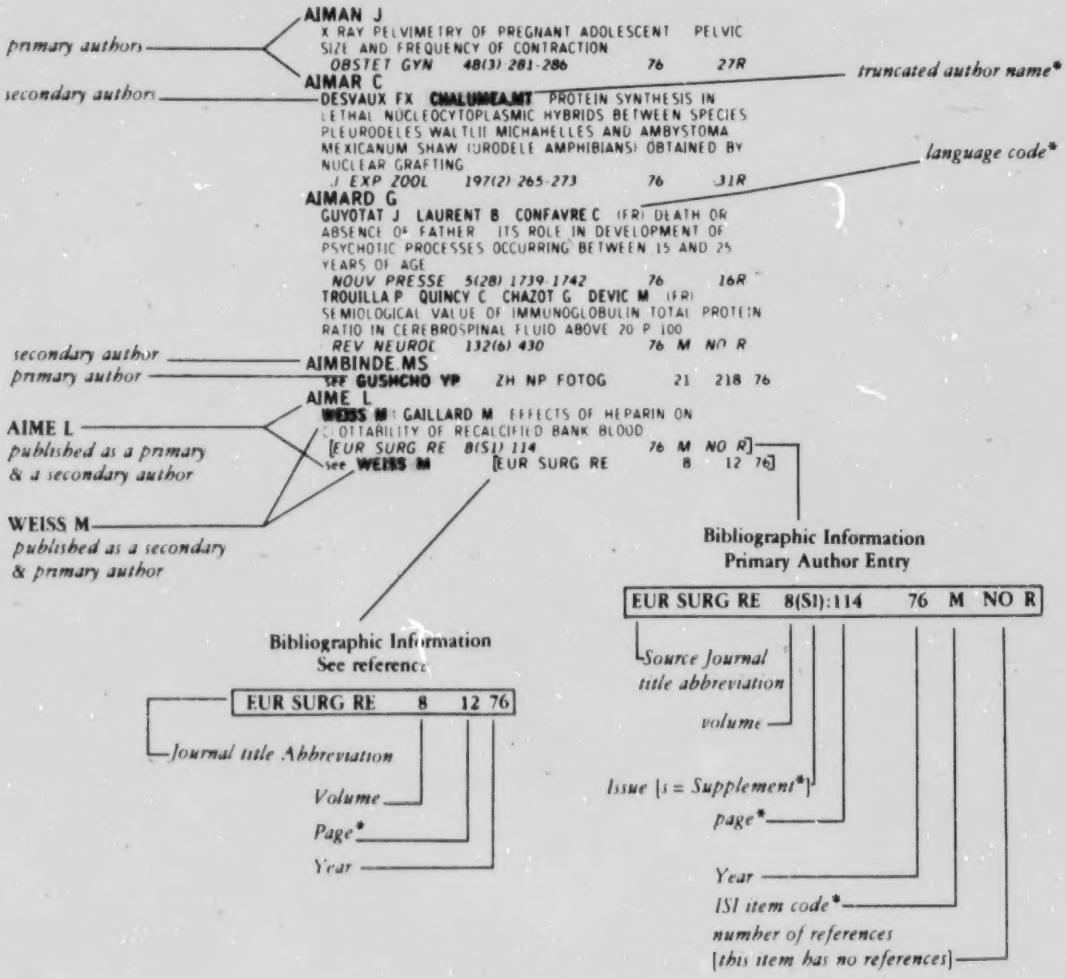
The Source Index of the *SCI* is an alphabetic listing of the primary and secondary authors who published items in *SCI*® source journals during the period covered. Anonymous items are listed first and arranged by journal title abbreviation.

ISI® uses the order of presentation to determine primary authors of multi-authored items, i.e., the first author is considered the primary author. Under the names of primary authors, you will find: the item's title, preceded by the item's secondary author(s) when applicable, and a bibliographic description comprised of source journal title abbreviation, volume, issue, beginning-ending pages, year of publication, an ISI item code, and the number of references.

Under secondary author names are found *see* references to the primary author and sufficient bibliographic information (source journal title abbreviation, volume, beginning page, year) to identify the item's corresponding entry under the primary author name.

When author names appear as both primary and secondary authors in the same time period, the information for items of primary authorship is presented first and the information for items of secondary authorship is presented last.

Sample Display


primary author
secondary author
truncated author name*
language code*
secondary author
primary author
AIME L
published as a primary & a secondary author
WEISS M
published as a secondary & primary author
AIMAN J
X RAY PELVIMETRY OF PREGNANT ADOLESCENT PELVIC SIZE AND FREQUENCY OF CONTRACTION
OBSTET GYN 48(3) 281-286 76 27R
AIMAR C
DESVAUX FX CHALUMEAU MT PROTEIN SYNTHESIS IN LETHAL NUCLEOCYTOPLASMIC HYBRIDS BETWEEN SPECIES PLEURODELES WALTLII MICHAHELLES AND AMBYSTOMA MEXICANUM SHAW (URODELE AMPHIBIANS) OBTAINED BY NUCLEAR GRAFTING
J EXP ZOOL 197(2) 265-273 76 31R
AIMARD G
GUYOTAT J LAURENT B CONFAVRE C (FR) DEATH OR ABSENCE OF FATHER ITS ROLE IN DEVELOPMENT OF PSYCHOTIC PROCESSES OCCURRING BETWEEN 15 AND 25 YEARS OF AGE
NOUV PRESSE 5(28) 1739-1742 76 16R
TROUILLA P QUINCY C CHAZOT G DEVIC M (FR) SEMIOLOGICAL VALUE OF IMMUNOGLOBULIN TOTAL PROTEIN RATIO IN CEREBROSPINAL FLUID ABOVE 20 P 100
REV NEUROL 132(6) 430 76 M NO R
AIMBINDE MS
SEE GUSHCHO YP ZH NP FOTOG 21 218 76
AIME L
WEISS M GAILLARD M EFFECTS OF HEPARIN ON CLOTTABILITY OF RECALCIFIED BANK BLOOD
[EUR SURG RE 8(S1) 114 76 M NO R]
see WEISS M [EUR SURG RE 8 12 76]
Bibliographic Information
See reference
EUR SURG RE 8 12 76
Journal title Abbreviation
Volume
Page*
Year
Bibliographic Information
Primary Author Entry
EUR SURG RE 8(S1):114 76 M NO R
Source Journal title abbreviation
volume
Issue [s = Supplement*]
page*
Year
ISI item code*
number of references
[this item has no references]

*See SCI Codes and Conventions *for further information*

Figure 2, from "Science Citation Index"

6. Dimensions of bibliometrics

Documents can be of an almost endless variety as witness the futile efforts of catalogers in trying to invent comprehensive rules for the description (bibliographic "control") of documents. Even the most elaborate rules for cataloging are designed for only a few of all the existing features and characteristics of a document. Bibliometric studies can consequently be (and are) of similar variety. Any attempt at providing an outline of bibliometrics must thus first of all be concerned with a reduction of the variety by aggregating similar studies. Even a cursory examination of bibliometric studies reveals, however, that a large number of distinctions need to be introduced.

An attempt has been made in the following to cluster the possible features of bibliometric study into "dimensions", each of which will be described in some detail. The dimensions cannot however be made "orthogonal", i.e. independent of each other.

1. Collection characteristics
2. Objects of the study
3. Source detail
4. Level of aggregation
5. Variables
6. Time perspective
7. Methods
8. Approach
9. Purpose

These dimensions with their subdivisions can be used as a basis for a classification/indexing system in describing bibliometric studies. The number of dimensions, the allocation of variables to dimensions etc would then need a more detailed study.

6.1 Collection characteristics

The collection of document representations used for the study can be defined in terms of

a) form, whether representations of e.g. monographs, journals, reports or patents are included, singly or jointly, in the collection. Each of the forms has its own bibliometric characteristics and each form is therefore usually separated, also when the study covers several forms.

b) type, whether articles, letters, news items, notes etc are included or not, singly or jointly. (A simple distinction between form and type is that the former applies to a carrier form and the latter to a message type.)

c) subject, whether a specific subject (discipline) is studied or a set of authors, institutions etc.

d) sampling procedures, if used.

6.2 Objects of the study

A study can, within a specified collection, be made on three different objects (which of course also can be combined).

a) Document representations, the study can be made on a set of document descriptions derived e.g. by sampling a national bibliography, or the volumes of a journal.

b) References, the study is in this case concentrated on an analysis of the references in a document or a set of documents.

c) Citations, likewise an analysis of the citations to a document or a set of documents.

There are three possible combinations of the three primary objects.

ab) Document representations vs references, the interest is in this case usually in the comparison of the characteristics of the set of document representations with its set of references, e.g. the language distributions of a set and its references.

ac) Document representations vs citations, both a set and the citations it receives are studied in detail.

abc) Document representations vs references vs citations, the characteristics, structure and relationships of a set of documents are analysed and mapped.

The fourth possible combination, citations vs references is either meaningless (since citations and references exist only in relation to a donor or a recipient) or is included in the last combination.

6.3 Source_detail

A bibliometric study can be more or less detailed depending on the source(s) used for collecting the data and their richness. It is possible to distinguish at least four levels of increasing detail.

a) The collection of document representations or references/citations studied is used with only the data that are available in it. Usually a collection (which mostly has been compiled for other purposes) is quite meagre in details of interest to a bibliometric study and there are large differences and incompatibilities between different collections.

b) Information inherent (and often implicit) in the collection, e.g. subject classification, is added and utilized.

c) Information available by examining the corresponding documents is added. In this case it is possible to distinguish two subcases:

   c1) Information that adds to the formal description of the document. Some journals have an editorial policy of not including titles of journal articles in references, all the co-authors might not be named, a subtitle is lacking etc.

   c2) Information gained by actual perusal of the document, usually matters of content, or in the case of references/citations e.g. their purpose: critique, verification, history.

d) Information is added from other sources, if e.g. the institutional affiliation of a set of authors is of interest then that is often not indicated, neither in references/citations nor on all documents.

Each increase of detail also adds to the labor for the study. A study on the first level is done easily and quickly in most cases, but if additional information is needed, with the concomitant consultation of other material, then the study is difficult and prolonged. The results are, however, also usually much more rewarding.

6.4 Level of aggregation

Bibliometric studies can be done at varying levels of aggregation:

a) Individual documents, where a journal article, a conference report, a book etc is a unit of the study.

b) All the output of one or several authors, institutions, journals etc are, after identification and description, aggregated for study, (e.g. publication analysis and evaluation for a number of institutions).

c) Bibliometric characteristics for e.g. universities, regions or countries, broad disciplines are studied

-

-

-

d) Ultimate level of aggregation, where the world's publication is considered.

6.5 Variables

A document representation in its most elementary form consists in the case of monographs of the name(s) of the author(s), title of document and imprint. Journal articles are usually represented by author name(s), title (but not always), journal title (usually abbreviated) and year, volume, pagination. Most references have this simple form, which has provided material for a large number of studies.

In the following an attempt will be made to identify the most obvious variables (features) of a document that can be analyzed in a bibliographic study using a journal article as an example. Each form of document has its characteristics which are mirrored in their representations. To discuss each of them is outside the scope of this paper, which only aims at indicating the possibilities.

6.5.1 Author

a) Name of (first) author including initials (it can for common names be difficult to distinguish different persons by name only).

b) Current (i.e. at time of writing the paper under consideration) institutional affiliation of the author, name of institution including department.

+ Address of institution, usually city and country is enough

+ Language(s) of country of institution

+ Subject area of institution

+ Type of institution, academic, industrial, governmental etc.

c) Permanent institutional affiliation, if different from current (i.e. if current is temporary).

+ Address

+ Language(s)

+ Subject area

+ Type of institution

d) Educational institution graduating the author.

+ Address

+ Language(s)

+ Level and subject area of degree

e) Country of origin of author.

+ Language(s)

6.5.2 Co-authors

Each of the details above is of course pertinent for the co-authors as well. In addition three variables are of interest for the set of authors of a paper.

a) Order among the authors, whether alphabetical, alphabetical with exceptions etc

b) Place of each co-author in order defined above (i.e. second, third etc)

c) Number of authors

6.5.3 Journal

a) Title and subtitle

+ Language(s) of title

b) Affiliated/sponsoring associations(s)/institution(s)

+ Address(es)

+ Language(s)

c) Publisher

+ Address

+ Language(s) of country of publisher

d) Language(s) used in journal

e) Subject area(s) covered by journal

f) Frequency of publication

g) Number of pages annually

h) Number of papers annually

6.5.4 Journal article

a) Title of article

b) Language

c) Subject area

d) Size of article

+ Number of pages

e) Year, month of publication

f) Volume, issue number, pagination

g) Date of receipt of manuscript

6.5.5 References/citations

Each reference/citation can in principle be described to the same detail as the source/recipient document itself. In addition there are a number of factors specific to the references qua references:

a) Function of reference: list of earlier work, description of methodology, falsification - verification of other results etc.

b) Part of cited document used, whole, part(s), idea, results, etc.

c) Location of references, in: introduction, methodology, result, conclusion etc.

d) Number of occurrences of references to each document or part(s) of it.

e) Number of references.

f) References in the same note/footnote, identification.

g) Number of references in each note/footnote.

h) Number of informal references, e.g. personal communication.

6.6 Time perspective

The time perspectives are essentially of two kinds:

a) static, i.e. the study is done as a "snapshot", describing the situation at a certain point of time

b) dynamic, tracing the evolution and growth is of main interest.

6.7 Methods

The methods used in most studies are usually straightforward, but a number of interesting techniques have recently been introduced for citation studies.

a) Frequency count, and correlation/regression calculations are the most common methods. The results of these studies are usually lists, graphs, tables.

b) Various "impact factors" based on the scaling of frequencies have been proposed.

c) Clustering using different measures and criteria has been utilized to a large extent, to map the structure of disciplines or relationships among journals, and for information retrieval.

d) Models, such as thermodynamic, epidemic models (interpretations of the same type of differential equation), Markov-chain processes have been tested on data from bibliometric studies.

6.8 Approach

Three main approaches to bibliometric studies can be found in the literature:

a) Simple descriptive studies

b) Descriptive - predictive studies

c) Model/hypothesis building/adaption and testing

6.9 Purpose

In a literature survey nine main purposes of bibliometric studies have been found. Each purpose will be discussed in more detail in the survey. They will thus be enumerated here.

a) Function and quality of references

b) The literature of ...

c) Scatter

d) Growth and decay, obsolescence

e) Quality assessment, ranking, evaluation

f) Trend analysis, prediction

g) Communication patterns

h) Structure mapping, science of science studies

i) Information retrieval

All of the dimensions and their subdivisions listed above could of course be extended, but no study has so far been identified that has taken into account more than a limited number of those mentioned above. A number of studies using other quantifiable measures, e.g. the colour(s) of books, can be envisaged and maybe found, but would fall outside the scope of bibliometrics as defined, i.e. concerned with written communication. The problem is not to extend, but to limit into manageable confines.

7. Survey of bibliometric literature

The literature in (and on) bibliometrics and citation is quite extensive. The bibliography by Hjerppe (15) lists more than 1 800. There are, in addition, 160 papers by Eugene Garfield, the most prolific writer on citation indexing/analysis, that were originally included in the periodical "Current Contents" under the title "Current Comments". These papers have not been included in the bibliography (15) since they are now listed and collected in Garfield's "Essays of an Information Scientist" (16).

The "Essays" cover the period from 1962 to 1976. During 1977 and the first half of 1978 Garfield has published a further 26 papers on citation indexing/analysis. The total number of papers to be considered is thus more than 2 000.

Obviously it is not possible within the scope of this outline to review even 10% of all that literature. There are furthermore a number of other papers reviewing the literature from various points of view. The literature survey will thus consist of

- bibliographies and general reviews
- brief presentation of seminal papers
- cursory analysis of purposes, methods and results of bibliometric studies
- short review of the writings of Garfield and Cawkell.

7.1 Bibliographies and general reviews

The bibliography (15) includes i.a. literature listed in the Guide & Journal lists for SCI (8) and the biblio-

graphy produced by ISI (17) and a review of bibliometrics by Narin & Moll (18). There is one major bibliography that time has not permitted to be screened, the "interim bibliography" by Pritchard (19) containing 700 items on statistical bibliography.

Narin & Moll (18) provide a review of bibliometrics with the following headlines:

- Publications
- References and citations
- Producers of scientific publications
- Modern bibliometric techniques
- Validity of bibliometric measures
- Bibliometric laws and distributions
- Application of bibliometric techniques
    - Librarianship and information management
    - The study of science and scientists

Donahue in a book (which has been heavily criticized in reviews) (20), based on his dissertation (21) attempts to show how various bibliometric methods can be applied to library management.

The report by Computer Horizons, Inc. (22) provides a thorough discussion of bibliometrics, especially the evaluative and structure mapping uses. Computer Horizons, Inc. has produced a number of other interesting bibliometric studies.

The book by Nicholas & Ritchie (23) gives a somewhat vague introduction to bibliometrics, not theoretical and not really practical.

Dobrov's book of 1966 (24) on the science of science and especially Nalimov & Mulechenko's book of 1969 (25)

on scientometrics (with a comprehensive quantitative approach to many aspects of the science of science) are witnesses both of the early and of the deep interest in the USSR in these matters. Two more recent Russian books in science of science, including scientometrics and bibliometrics are (26) on scientometric studies in chemistry, reviewed by Rabkin (27), and the book on sociology of science edited by Kelle & Mikulinsky (28). In Kiev has since 1969 been published the, maybe only, scientometric serial "Naukovedenie i Informatika". Lubrano (29) has recently reviewed Soviet studies of Science.

The book by Menard (30) on the growth and change of geology utilized very heavily bibliometric material and is together with the books of Price (31, 32) basic reading. The books by Crane (33), Cole & Cole (34), Zuckerman (35), Mullins (36) are primarily sociological studies, but utilize bibliometric measures to a large extent. Very recently has also been published a conference proceedings edited by Elkana et. al. (37) called "Toward a Metric of Science".

Citation indexing and analysis has been reviewed i.a. by Hall (38), Martyn (39) and Broadus (40). The "Essays ..." by Garfield mentioned earlier (16) also provide a conspectus of the citation field.

The books by Meadows (41) and Nelson & Pollock (42) give a good review of communication in science and engineering and the reports (43) and (44) contain large amounts of statistical data on scientific literature and communication.

7.2 Seminal papers

The first bibliometric study was apparently made in 1917 by Cole & Eales (45). They analyzed the literature of comparative anatomy, from 1543 to 1860. Their interest was partly in tracing the aspects of anatomy and the animals that were of interest to those engaged in comparative anatomy and partly in determining the dynamics of contributions by different countries, as measured by number of publications.

In 1923 Hulme was the first to use the term "statistical bibliography" for what is now called "bibliometrics" (46). He analyzed author and journal entries in the "international Catalog of Scientific Literature", for the period 1901-1913. The total number of journals was ranked by country showing that Germany during that period produced most, close to 30% of all journals, with France as second nation producing more than 10%. Hulme also analyzed the total number of author entries per year and discussed the relationships between scientific publication and general economic conditions and the growth of modern civilization.

In 1926 Lotka published his article (13), in which he, referring to investigations of a Decennial Index of Chemical Abstracts and Auerbach's "Geschichtstafeln der Physik", states that the number of people producing N papers is proportional to $1/N^2$. In other words, for every 1 000 authors producing 1 paper in a specific time period, there are $1\ 000/2^2 = 250$ who produce 2 papers, $1\ 000/3^2 = 111$ who produce 3 papers, etc, see figure 3.

In 1927 Gross & Gross (47) were the first to take the references in one volume of a journal and then rank

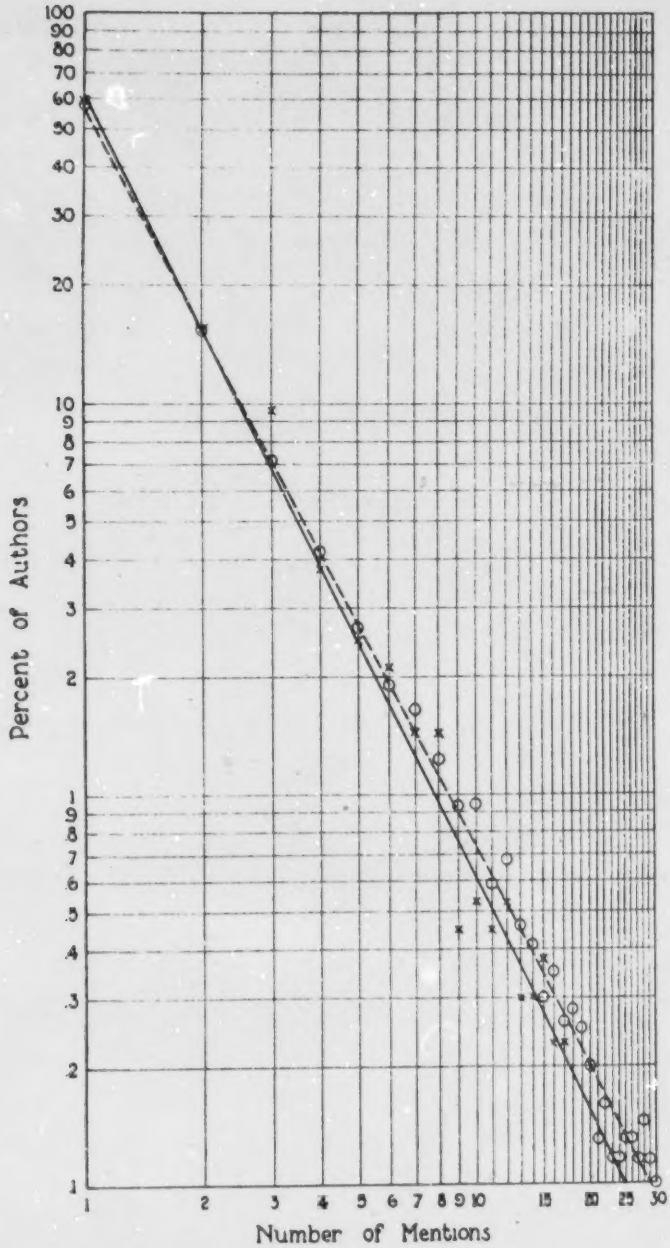
the cited journals by the number of citations they received. They also were the first to note the age distributions of the citations. The purpose of their study was to find out which chemistry journals were most essential to their college library. Their modest paper was followed by a large number of similar studies.

In 1934 Bradford first published his empirical observations on the concentration of articles in the scientific periodical literature (11). It did not receive much attention until summarized in his book (12). The literature on the Bradford distribution is after the 1960's very extensive. Bradford gave two somewhat different formulations, one verbal:

"if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject, and several groups or zones containing the same number of articles as the nucleus, then the numbers of periodicals in the nucleus and succeeding zones will be as $1:n:n^2: \ldots$*"*

In an accompanying graph he however placed the cumulative numbers of journals in that ratio, as pointed out by Vickery (48).

In 1936 Cason & Lubotsky were the first to use journal to journal citation analysis to study quantitatively the extent to which one subfield influences, and is influenced by, others (49). Their study was limited to English language journals in psychology published in 1933. They summarized their data in a 28 x 28 cross citation matrix for the most significant journals, and also noted and discussed many of the problems inherent



Logarithmic frequency diagram showing number of authors mentioned once, twice, etc., in Auerbach's tables (points indicated by crosses), and in Chemical Abstracts, letters A and B (points indicated by circles). fully drawn line indicates

FIGURE 3

PUBLICATION FREQUENCY FOR AUTHORS

from Lotka (13)

in citation studies, such as multiple references (op.cit., idem, etc), self-referencing, variations in journal abbreviations.

In 1945 Banay seems to have been the first to count citations for an impact assessment of publications (50). The use of 131 papers published by the research service of a hospital was measured by counting the references to them in 29 periodicals. The cited papers were classified by form (reports, books etc) and content (therapeutic, clinical, experimental etc).

In 1949 Zipf published his book (14), containing a wealth of data drawn from the most various fields, showing i.a. the distribution which applied to word frequency in a text states that the Nth ranking word will appear approximately K/N times, where K is a constant for that text.

In 1949 Fussler made a thorough study of the physical and chemical research literature by studying references in sets of journals derived by a first iteration (51). His objectives were to determine:

" 1. *The importance of the literature of various subject fields to chemistry and physics.*

2. *The temporal span of this literature, especially that between the data of an original publication and the data at which it is known to have been used.*

3. *The principal forms of the literature used and their relative importance.*

4. *The national origins of the literature used in the United States.*

5. *The more important serial titles for each field."*

In 1953 Stevens made a thorough review of the characteristics of subject literatures, synthesizing title and subject dispersion, language and form distribution and time spans (52).

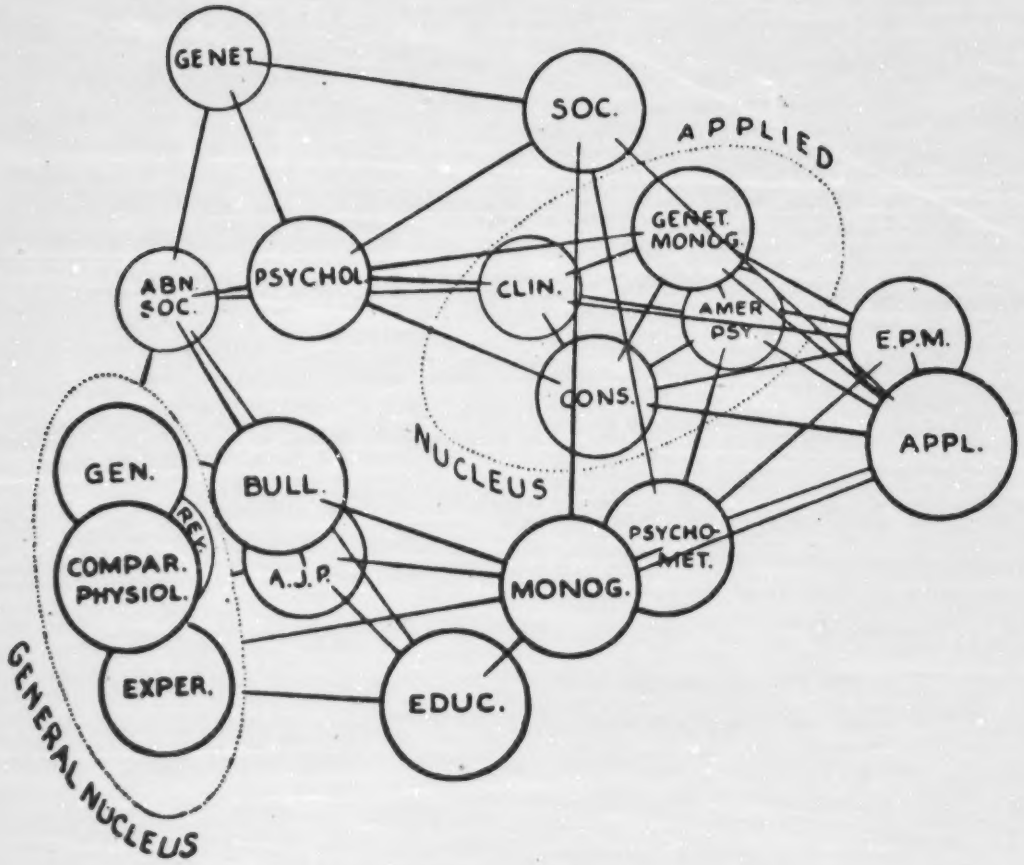
In 1953 Daniel & Loutitt in a book (53) on the development of psychology included data on literature growth rates. They apparently were the first to use cluster analysis and mapping techniques for journals based on citations. They also developed a 3-dimensional representation of the clusters, illustrated in figure 4.

In 1954 Dennis analyzed the bibliographies of eminent scientists (54) and the productivity of psychologists (55), taking up the work by Lotka of 1926.

In 1955 two papers, by Adair and Garfield respectively, (56, 57) proposed the production of a "Citation Index". The idea was derived from Shepherd's Index, a periodical listing citations to court cases. In his paper Garfield also emphasized the uses such an index could have for historical research, and for evaluating the impact of a particular work, while its main use is suggested to be for information retrieval.

In 1957 Clark did a study on eminent psychologists (58) and found that journal citation counts had the highest correlation with one of the other measures of eminence, votes received.

In 1960 Westbrook suggested, utilized and discussed the use of citation counts for evaluating research laboratories (59).



Three-dimensional representation of intercorrelations of psychology journals. Lines connect journals which are correlated .25 or more. Journals in the "general (or research) nucleus" are correlated about .95 with each other; those in the "applied (or professional) nucleus" about .80. The Psychological Monographs and the Journal of Psychology seem to serve as links between the general cluster on the left and the more complex cluster on the right.

FIGURE 4

THREE DIMENSIONAL REPRESENTATION OF INTERCORRELATIONS
OF PSYCHOLOGY JOURNALS
from Daniel & Louttit (53)

In 1960 Burton & Keebler proposed a measure for the decay in citations to older literature (60). They borrowed the model and term "half-life" from studies of radioactive decay.

In his very influential books "Science since Babylon", and "Little Science, Big Science" (31,32) Price discussed the growth of science and the development of its literature and the roles played by it. The books have had a deep impact on the field of bibliometrics (and are furthermore very enjoyable reading). Among other interesting observations he suggested "Price's law": "half of the scientific papers are contributed by the square root of the total number of scientific authors". In a sequel paper (61) he furthermore suggested that the cost of research is proportional to the square of the number of scientists.

In 1962 Bourne made an estimate of the world's scientific and technical literature (62). The study included estimates of origin language, subjects, and coverage by abstracting and indexing services.

In 1962 Dahling used citations to trace the diffusion of an idea (Shannon's theory of communication) and showed that some papers became sociometric "stars" while other became isolates (63).

In 1963 Kessler introduced "bibliographic coupling" (64), i.e. the number of references two papers have in common, as a measure of their similarity, and then showed that a clustering based on this measure yields meaningful groupings of papers for information retrieval.

In 1963 the first Science Citation Index (SCI) is produced, covering the literature of 1961. The first SCI covers 613 journals and contains 1.3 million references.

In 1964 Goffman proposed a generalization of epidemic theory and its application to the transmission of ideas (65).

In 1964 Garfield, Sher and Thorpie, compared the history of DNA, as told in Asimov's "The Genetic Code", with the citation network found in SCI (66), and found strong relationships.

In 1965 Price, using the SCI, published a very influential paper discussing the pattern of the network of papers interlinked by references and the use of this pattern for defining the nature of the research front (67). He also discussed productivity, as measured by citations instead of publications.

In 1965 Kaplan (68) reviewed the patterns of citation behavior and discussed citations in relation to the social structure of science.

The number of interesting studies after 1965 becomes too large and the studies too varied, making it very difficult to designate some of them as seminal. The most interesting of them will be mentioned further on in the review.

7.3 Function and quality of citations

One of the key issues in citation analysis, especially in its use for evaluation, has been the question of the function, quality, validity etc of citation practices. At least 35 papers can be found in (15) on this

subject, which includes the problems of eponomy (i.e. the giving of a person's name to a natural law or phenomenon e.g. Hall effect) which often substitutes a formal citation, reasons for citing, for which Garfield (69) provides the following list:

1. Paying homage to pioneers
2. Giving credit for related work (homage to peers)
3. Identifying methodology, equipment, etc
4. Providing background reading
5. Correcting one's own work
6. Correcting the work of others
7. Criticizing previous work
8. Substantiating claims
9. Alerting to forthcoming work
10. Providing leads to poorly disseminated, poorly indexed, or uncited work
11. Authenticating data and classes of fact - physical constants, etc
12. Identifying original publications in which an idea or concept was discussed.
13. Identifying original publication or other work describing an eponymic concept or term, as e.g. Hodgkin's disease, Pareto's Law, Friedel-Craft's Reaction, etc
14. Disclaiming work or ideas of others (negative claims)
15. Disputing priority claims of others (negative homage)

Referencing as persuasion, self-citations, uncitedness, accuracy of citations, relationship between where in the text citation is made and the amount used of the cited work, are also some of the topics. In a recent study Moravcsik and Murugesan (70) have investigated the actual citation practice using the following classification of references:

1. Is the reference conceptual or operational
2. Is the reference organic or perfunctory

3. Is the reference evolutionary or juxtapositional (i.e. built on the preceding or an alternative to it)
4. Is the reference confirmative or negational

This classification was elaborated upon by Chubin & Moitra (71) who suggested that affirmative citations are either essential or supplemental and that essential citations can be basic or subsidiary, supplementary citations provide additional information or are perfunctory. Negational citations can be partly or totally negational.

The paper by Griffith ,Drott & Small (72) discusses some of the basic assumptions underlying citation analysis.

The development of bibliographic entries in the 17th century has been studied by Zaremba (73).

7.4 The (... of the) literature of ...

This subset of bibliometrics is very large, in the order of hundreds of papers, and their titles have the structure indicated above e.g. "The language distribution of the literature of Geology" on "The literature of Schistosomiasis". The literatures studied range from astronomy and geography through dentistry and computer science to European sociology and environmental education. Most of the studies identify the core journals, the distribution of publications by country and language and form. Often the journal article distribution is tested against the Bradford distribution, with more or less fit, and the growth and decay rates are calculated. Sometimes the references are counted and analyzed and used for a citation ranking exercise. The results vary between fields and subjects. The greatest problem with all these studies is their lack of com-

patibility, which makes comparisons and synthesis very difficult.

7.5 Scatter, the Bradford - Zipf - Lotka distributions

The bibliometric distributions describing the scatter or dispersion of literature, words and authors respectively, have generated very many theoretical papers, trying to consolidate them or deduce them. All three of these distributions have been linked to each other. Among the recent papers Bookstein (74) has tried to illuminate the relationship among the three distributions, Praunlich (75) offers a new formulation and shows that the deviation from linearity at the end of the distribution, which has been the subject of long discussions, is an intrinsic feature. Allison et. al. (76) discuss the relationship between Lotka's law and Price's law.

Price has proposed a "cumulative advantage" distribution (77). The underlying probabilistic theory of processes in which success breeds success, but failure is not punished, is claimed to be appropriate for the three bibliometric distributions as well as the Pareto distribution. The obsolescence factor for literature use can be derived as a side result.

The practically oriented papers in this group discuss the application of Bradford's distribution to library collections, or try to fit their empirical data to it.

7.6 Obsolescence

Obsolescence, the fact that literature usage usually declines with age, is also the subject of a large

literature. Line & Sandison have in a comprehensive review (78) of 200 papers summarized their data and made some clarifying distinctions between synchronous and diachronous studies and their results. The relationship between the growth of a given literature and the time distributions of references from a given year are connected since the fraction of the publications from more recent years would be increasing in a rapidly growing field. The average reference in such a field would consequently be to recent publications.

The obsolescence problem is of interest to librarians in their assessment of the value of back issues of old periodicals.

Menard (30) discusses at length the relationship between the growth rate of a field and bibliometric measures. Motylev (79) reviews and criticizes existing methods for measuring utilization rate of documents of different age. Clark (86) has studied the obsolescence of patents.

7.7 Quality assessment, ranking, evaluation

The uses of bibliometric analyses for evaluative purposes is perhaps the issue that has generated the most discussions. Three levels of evaluation can normally be distinguished

a) evaluation of individual authors or of institutions
b) evaluation of journals
c) evaluation of countries

A comprehensive review of the whole area is available in (22). The evaluation of individual authors, especially the use of citation counting, is of course the most

controversial area. Publication counting, though objected against, has never met the same violent critique. However, Narin has in his report (22) a thorough review of twenty-four studies in which bibliometric measures, publication and citation counts have been correlated with other measures of eminence such as awards, listings and academic rank or affiliation. In almost all cases the bibliometric measures for groups of scientists are correlating reasonably well, from 0.5 to 0.8, with the other measures.

Any attempt to use the SCI for evaluative citation counting without full knowledge of its limitations is bound to meet a number of pitfalls. Some of the special problems are:

a) Multiple authorship, only the first author is listed in SCI, so that for a true citation count for an individual all the publications which he has co-authored with someone else as first author must be looked up under that name (a publication list is therefore needed). There is also a problem in allocating credit for multiple-author papers. Should they be counted on equal basis as a single author paper or divided proportionally? How does one consider the contribution indicated by the ordering of names?

b) Self-citations, controlling self-citations for single authors is easy but for a multi-authored paper each citation has to be checked so that it is not by anyone of the other authors.

c) The homonym problem, many scientists with the same name and initials publish in the same field, a scientist can also change field so that titles from different fields of cited papers cannot always be

used to differentiate two authors.

d) Field variations, the citation and reference rates vary greatly in different fields, e.g. engineering averages 6 references/publication and 5 citations/publication whereas chemistry and physics average 12 and 14 references/publication respectively and 13 citations/publication and biomedicine tops with 18 references/publication and 20 citations/publication.

e) Short term fluctuation, there can be large variations in the citation frequency of a paper from one year to another.

f) Errors, made by citing author/journal, in many cases a single letter can be critical.

Studer and Chubin (81) have recently raised the ethical question whether the use of unobtrusive measures such as citations sidesteps the issue of informed consent.

The evaluation of journals by citation counting has also been the subject of discussions. Their relevancy for library applications have been questioned as there have been shown in some cases to be large discrepancies between journal rankings produced by citation counting and by loan requests.

Publication and citation counting has also been used to compare output and impact of a nation's research effort. The distribution of world science has thus been the subject of recent papers by Bakker & Chang (82), Frame (83), Inhaber (84) and Narin & Carpenter (85). Tables 6-8 show the results of a citation to publication comparison for different countries in different disciplines.

A large number of papers have also discussed various sociological aspects of evaluation, such as the competition and reward system in science, the Matthew effect and the Ortega hypothesis, quality and quantity, continuity of productivity, age and achievement. Nobel laureates and their citation profile before and after the prize and the conflicting views of Popper and Kuhn on the development of science have also been tested by bibliometric methods.

7.8 Trend analysis and prediction

The identification of trends, and predictions made on the basis of trends have also been the subject of many papers. In the Soviet Union this kind of studies has received a special interest and there are a number of papers on utilization of patents for prediction. A typical example is the paper by Pechatnikov (86).

7.9 Communication patterns

Bibliometrics, and especially citation analysis, has also been used in the study of scientific communication. Typical studies are formal and informal communication, publication vs communication, co-authorship and interorganizational mobility. Other studies investigate the role of dissertations, reports, conference proceedings as information sources.

TABLE 6

CITATION TO PUBLICATION MEASURE FOR CITATION TO THE U.S.
from Narin & Carpenter (85)

Citing Country	Cited and Citing Discipline							
	Math.	Eng.	Phys.	Chem.	M.Bio.	Med.	S.Bio.	Psych.
U.S.	1.34	1.49	1.53	1.87	1.53	1.61	1.38	1.09
U.K.	1.08	1.00	1.40	1.47	1.31	1.03	.74	.86
W. Germany	1.10	.89	1.24	1.20	1.21	1.02	.79	.93
France	.88	1.16	1.23	1.33	1.27	1.19	.78	1.03
U.S.S.R.	.64	.38	.66	.83	1.06	1.00	.56	.62
Japan	1.08	1.18	1.43	1.46	1.31	1.45	.86	1.02
World	1.24	1.20	1.32	1.47	1.41	1.34	1.12	1.06
Non-U.S.	1.11	.96	1.22	1.31	1.30	1.13	.88	.95

TABLE 7

CITATION TO PUBLICATION MEASURE WITHIN EACH COUNTRY
from Narin & Carpenter (85)

To	From	Discipline							
		Math.	Eng.	Phys.	Chem.	M.Bio.	Med.	S.Bio.	Psych.
U.S.	U.S.	1.34	1.49	1.53	1.87	1.53	1.61	1.38	1.09
U.K.	U.K.	2.46	2.05	1.48	1.57	1.67	2.08	3.18	2.49
W. Germany	W. Germany	2.95	3.94	1.71	4.10	1.89	2.72	4.78	8.11*
France	France	3.33	5.24	1.22	2.60	1.86	3.48	5.53	3.45*
U.S.S.R.	U.S.S.R.	10.20	9.95	3.05	2.54	4.54	9.65*	26.47*	42.85*
Japan	Japan	8.00	3.63	3.20	2.02	2.85	3.02*	6.69*	4.68*
Other	Other	1.15	1.18	1.05	1.12	.83	.93	1.10	1.12

*Indicates "Cited Country's Publications in Field/Total Publication in Field" < .02

TABLE 8

CITATION TO PUBLICATION MEASURE FROM OUTSIDE EACH COUNTRY
from Narin & Carpenter (85)

To	From	Discipline							
		Math.	Eng.	Phys.	Chem.	M. Bio.	Med.	S.Bio.	Psych.
U.S.	Non-U.S.	1.11	.96	1.22	1.31	1.30	1.13	.88	.95
U.K.	Non-U.K.	.93	.62	.82	.93	1.06	.93	.99	.75
W. Germany	Non-W.Ger.	.95	.45	.82	1.27	.52	.28	.64	.44*
France	Non-France	.18	.68	.64	.62	.41	.27	.52	.34*
U.S.S.R.	Non-U.S.S.R.	.14	.20	.33	.13	.09	.08*	.24*	.14*
Japan	Non-Japan	.64	.78	.64	.66	.67	.74*	.61*	.35*
Other	Non-Other	.86	.74	.81	.79	.68	.67	.69	.88

*Indicates "Cited Country's Publications in Field/Total Publication in Field" < .02

7.10 Structure mapping and the growth of disciplines

An area which recently has received a lot of interest is the structure mapping or development and growth description of subject specialities or groups of journals. One of the techniques used is clustering, whereby some defined measure of relationship, and criteria, are used to generate groups or clusters. These studies are usually performed with the aid of a computer. The concept of bibliographic coupling originally developed by Kessler (64) was used for clustering but has now been replaced by co-citation, a measure developed by Small (87). (Two papers that have a number of papers in common in their list of references, have a bibliographic coupling equal to the number of papers in common. Two papers are co-cited when they are jointly cited in one paper, if two papers repeatedly co-occur in the lists of references then their co-citation strength increases.) Co-citation is a measure that changes with time but bibliographic coupling is static. These measures have been used in a series of studies to give a mapping of the micro- and macro-structure and relationships of disciplines and journals and to depict their evolution. In fig. 5 is illustrated a co-citation network for frequently cited papers in particle physics. Three recent articles illustrate the status today. Small (88) using the co-citation measure and his "circle and hill" model for displaying the data, applied on SCI data, provides a longitudinal study of the development of collagen research. In Sullivan, White & Barboni (89) is also a bibliometric study (but of weak interactions) done on a comprehensive bibliography compiled for the purpose, including its citations. The bibliography was analyzed to show various developments in the field of weak interactions

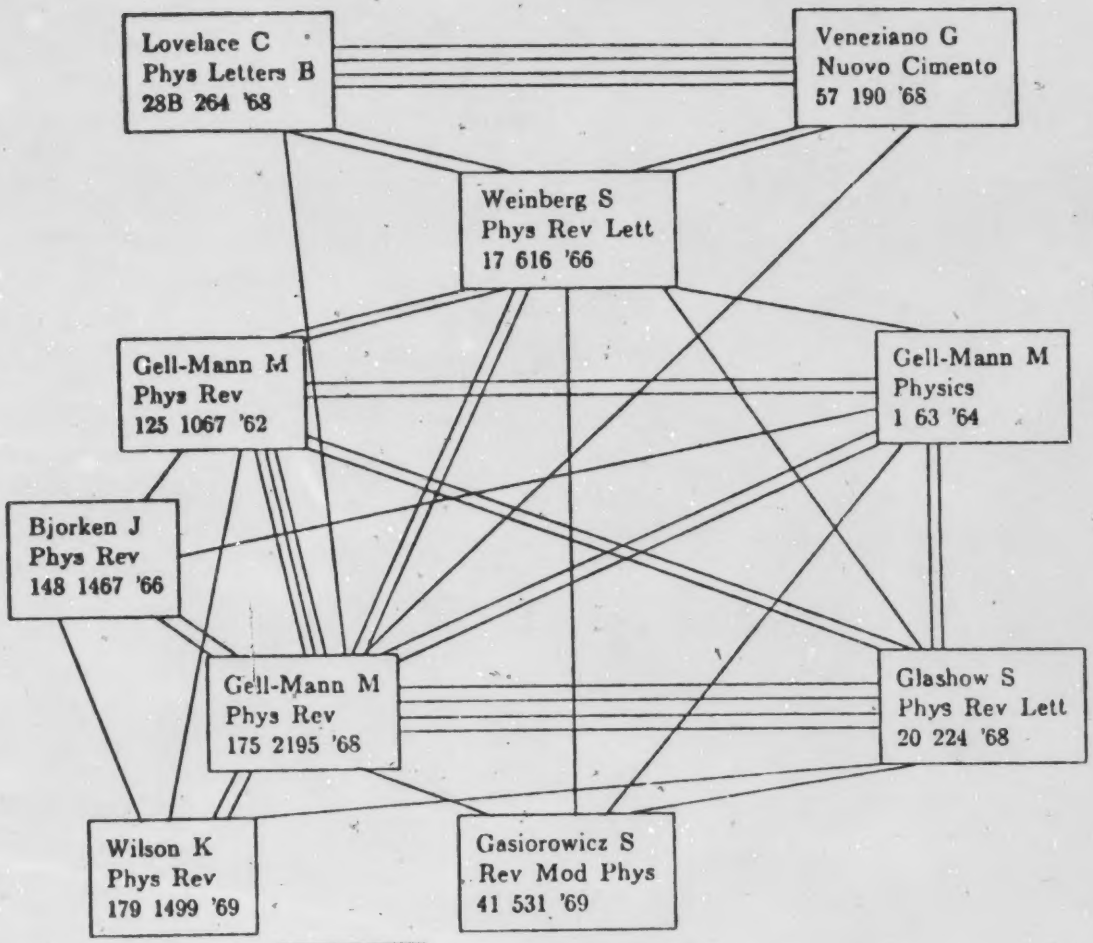


FIGURE 5

CO-CITATION NETWORK FOR FREQUENTLY CITED
PAPERS IN PARTICLE PHYSICS
from Small (87)

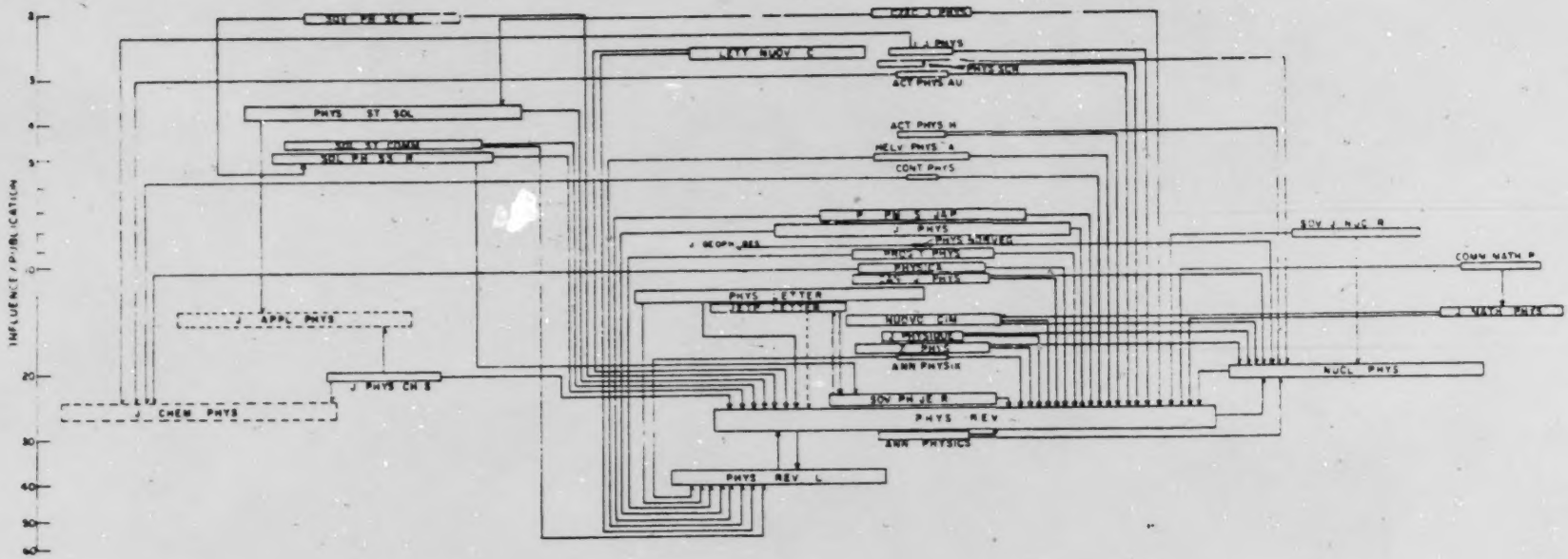


FIGURE 6

INFLUENCE MAP FOR GENERAL, SOLID STATE
AND NUCLEAR PHYSICS JOURNALS

from NARIN (22)

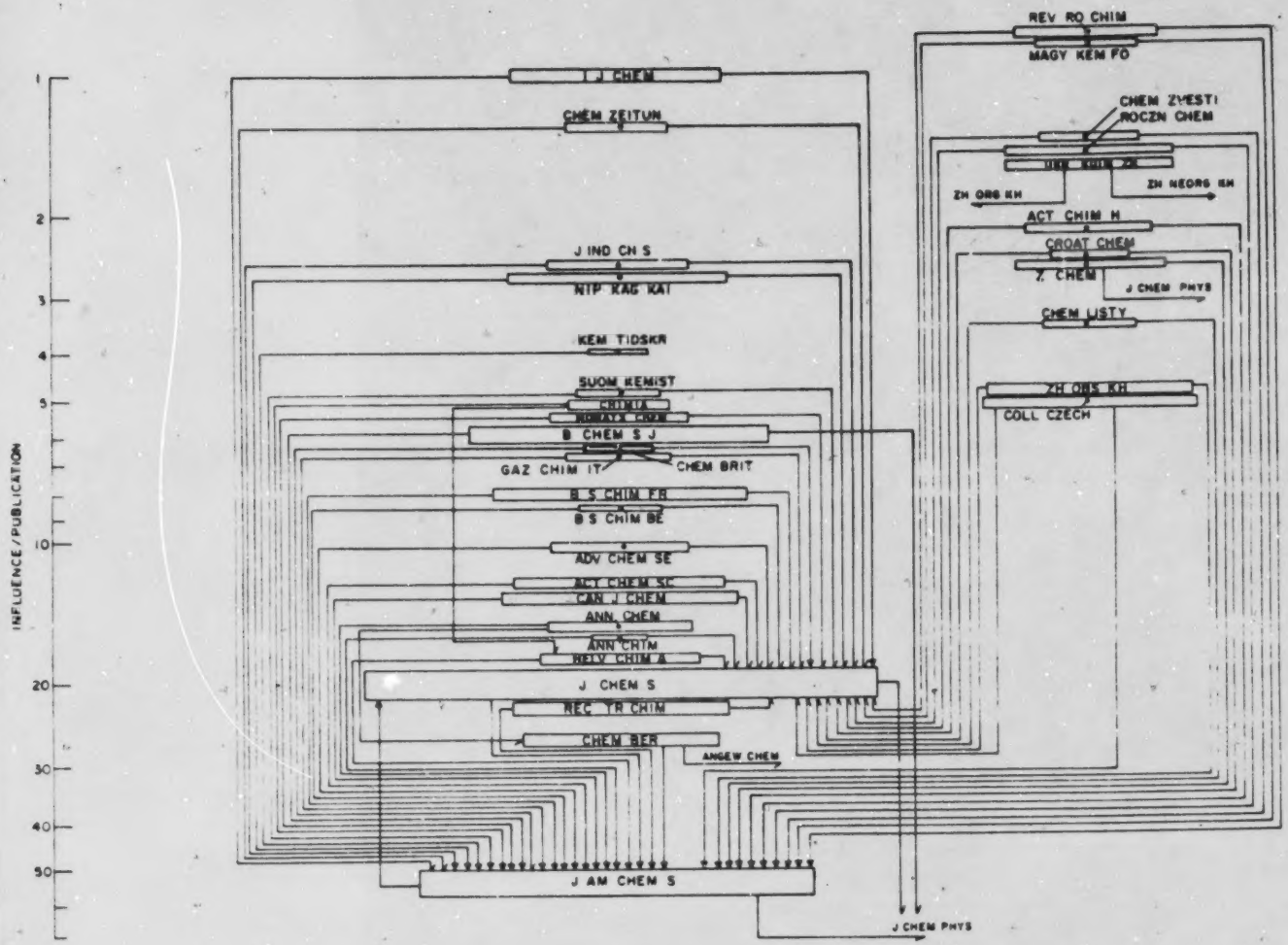


FIGURE 7

INFLUENCE MAP FOR GENERAL CHEMISTRY JOURNALS

from NARIN (22)

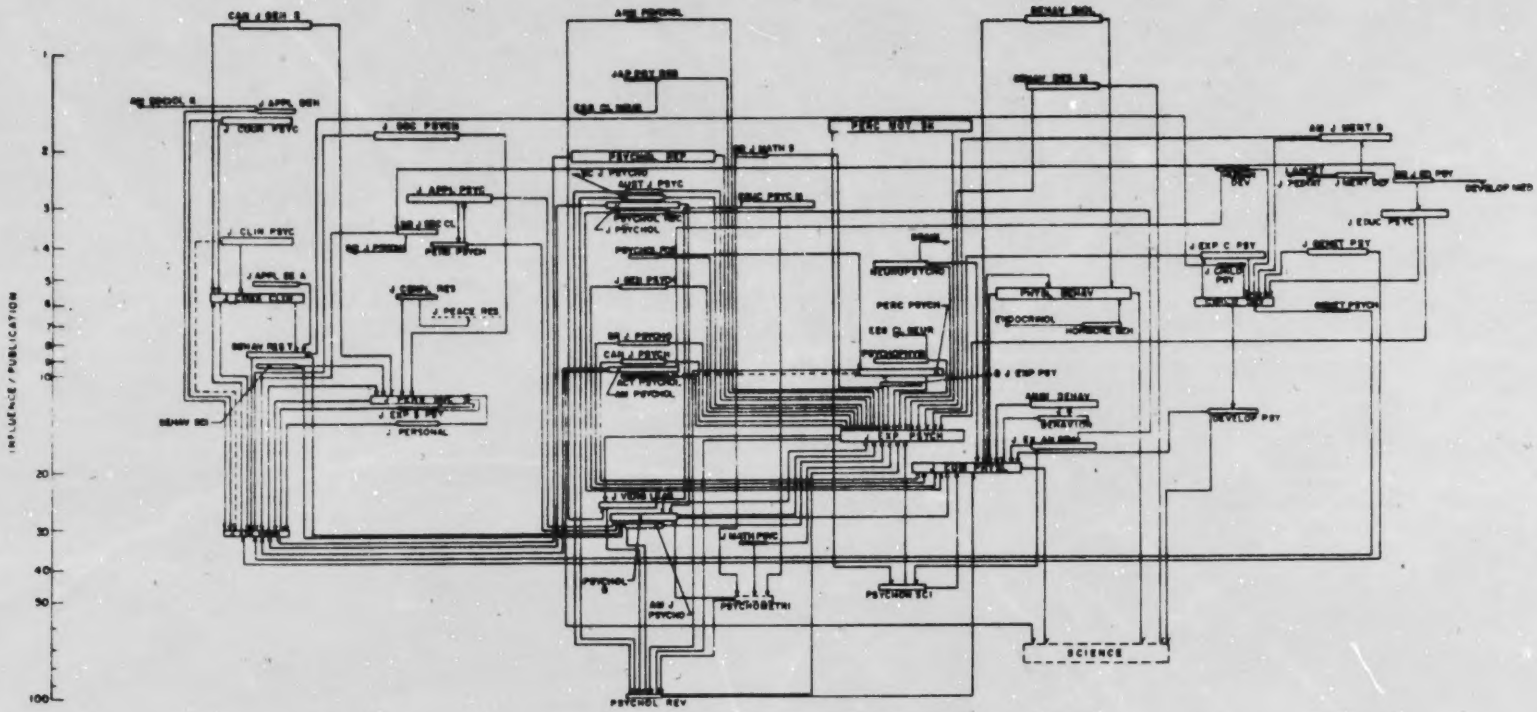


FIGURE 8

INFLUENCE MAP FOR PSYCHOLOGY JOURNALS

from NARIN (22)

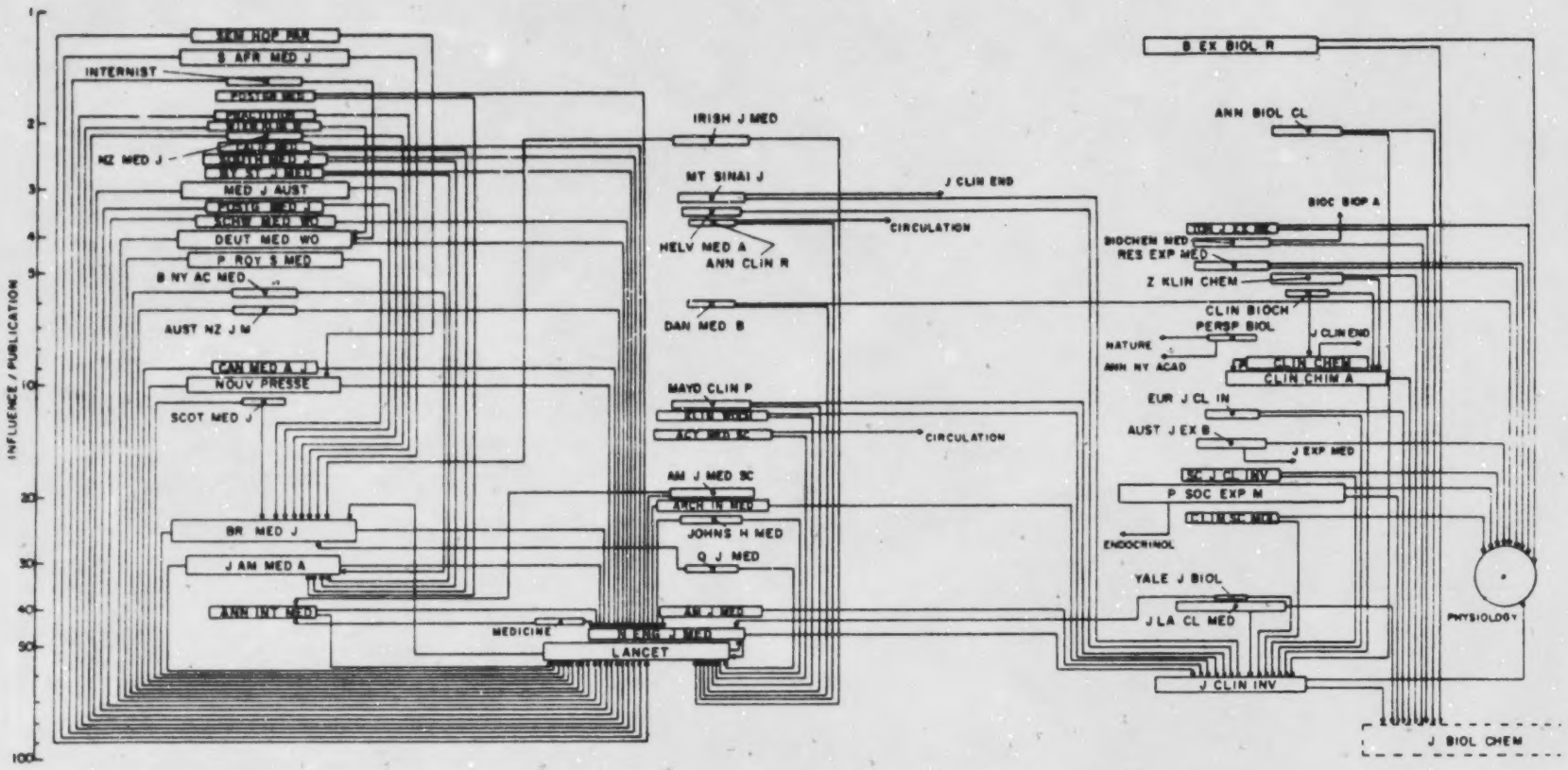


FIGURE 9

INFLUENCE MAP FOR GENERAL AND INTERNAL MEDICINE/CLINICAL SCIENCE JOURNALS

from NARIN (22)

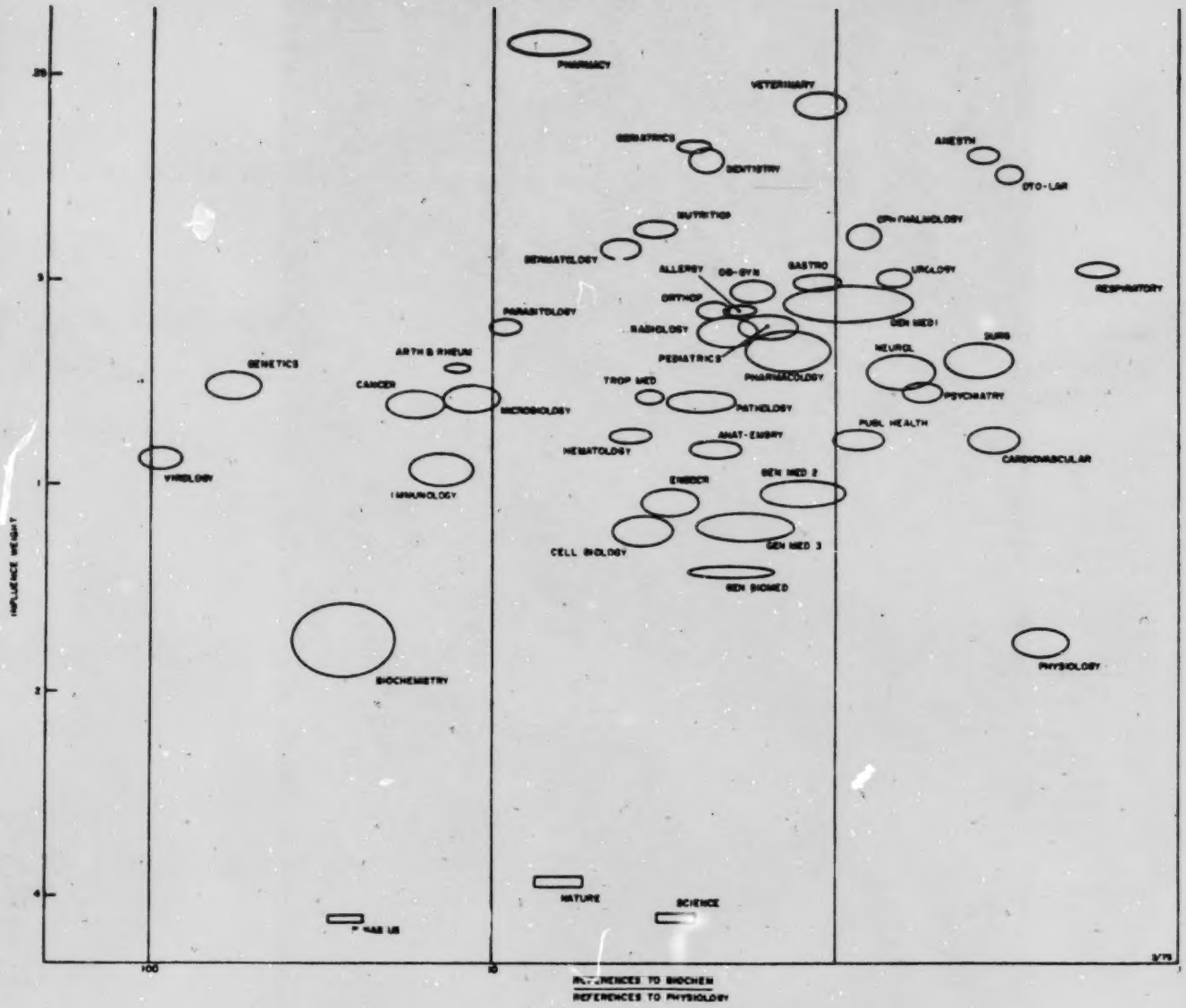


FIGURE 10

INFLUENCE STRUCTURE FOR THE BIOMEDICAL LITERATURE
from NARIN (22)

and the effect of some critical events. Experience from this study provide the authors with an opportunity to evaluate (90) the study of Small and the co-citation technique.

For the description of the relationships between journals Narin (22) has developed a method called the influence methodology which uses three influence measures. With these measure it is possible to make maps that display the hierarchies of influence among journals. A remarkable fact is that these methods give a picture of a quite strict "pecking order" among journals in science as illustrated by fig. 6-10.

7.11 Information retrieval

Bibliometric techniques are used in information retrieval mainly for two purposes, the Bradford distribution is used to estimate the comprehensiveness of a specific bibliography and the citations have been used for clustering documents into groups on the same subject, thereby alleviating retrieval. The SCI and SSCI are of course in themselves valuable tools for retrieval also.

7.12 Garfield & Cawkell

The paperflood by Garfield deserves special mention, first of all because of its volume and secondly because of the variety. The writings of Cawkell, not as profuse nor so varied are still in the same vein.

Any attempt at summarizing Garfield's papers is bound to fail. His production can be divided into two parts.

1) The "Current Comments" originally published in "Current Contents" and now available as "Essays ..." (16). A number of themes of interest to bibliometrics can be discerned in these essays. He has used the resources of ISI, the producer of SCI, SSCI, Current Contents to do a series of interesting studies, e.g.:

   - The journal citation studies, in which the citation characteristics of a journal or a set of journals is presented, ranging from the core literature of chemical physics, through Journal of American Medical Association vs New England Journal of Medicine, journal self citation rates, to a survey of journals from various countries, what they cite and who cites them. (In appendix I are reproduced two studies of Scandinavian journals).

   - Lists of exceptionally highly cited articles, highly cited articles in various subjects, journals and countries.

   - He also introduced the concept of "citation classic", asking the authors of the most cited articles to comment on them.

   Apart from these recurring themes there are essays commenting upon most aspects of bibliometrics and citation analysis, but especially evaluative uses and science of science studies.

2) Garfield has also published a large number of journal articles, mostly related to the subjects of citation indexing and analysis.

(A very notable event for bibliometrics and citation analysis was the reaction to an article by Garfield

published in "La Recherche" on the theme: "Is French Science too provincial?" He claimed, with a basis in citation analysis, that the French are primarily cited by the French, that the French journals have a limited dissemination, that the more distinguished French scientists publish in foreign journals.

The response was intense starting from replies by the former Prime Minister Michel Debré and various professors defending the French language as a language for science and ending in accusations of linguistic imperialism and perniciousness, while some recognized the status of English as the language of science today.)

8. Conclusion

Bibliometric studies and techniques have been successfully used in a large variety of applications. So far most of the studies have been relatively simple compilations of data and statistics. Even so they have yielded a vast amount of interesting and sometimes surprising results. The main problem encountered has until now been the laborious collection of data by manual methods, with the ensuing limitations on scale, and maybe on validity. The existing large files of machine-readable bibliographic data, national bibliographies (still mostly incompatible) can alleviate parts of a bibliometric study. There is, however, no substitute for imagination and perception of essentials. Volumes of data can yield meaningful answers only to pertinent questions.

Large scale interactive information retrieval systems are making the crude extraction of raw data for biblio-

metric studies easy, but there are still missing systems for interactive data wrestling and hypothesis testing, once the raw data are collected. All the studies on "the literatures of ..." and on obsolescence are still scattered and unconnected. A great task remains in the bringing together of this type of studies and results and in follow-up studies as a basis for theory building and hypothesis testing, which to a large extent is lacking.

One major difficulty for future bibliometric studies is the fact that we have only one relation for associating documents, the reference/citation, the nature of which we know very little about. Studies are needed on the growth and development of the practice of citing, from the informal ways in the 17th century (still prevalent in the arts and humanities) to the rigorous forms established in the late 19th century. Meadows has indicated in (41) that one of the causes of this change might be that, as the scientific literature grew, the greater became the need for accurate identification. When books were written sparsely then a mention in the text of the book by a certain author was enough. The introduction of the journal article facilitated greater productivity and the start of the exponential growth of literature. Others, such as Price (31) and Kaplan (68), attribute the emergence of the formal reference practice to the tension between competition and secrecy on one hand and the need for access to the results of others on the other hand.

There is a pressing need to know more about the accuracy, the pertinence and selection criteria of references within disciplines and across them. Why is a researcher in bio-medicine providing three times more

references than one in mathematics or engineering? Is that "habitual" difference based on functional need or socio-cultural pressure?

There is also a need to develope and utilize the implicit relations of association, e.g. by surveying co-authorship. Can other papers written by people who have once participated in a paper be considered to be associated and a measure be developed? Similarily for institutions, can papers written by people at the same institution be considered to be associated? How can the now frequent practice of "visiting professorship" be utilized to associate institutions and their papers? How do we utilize the association inherent in different papers being published in one book? Under what conditions could these associations be put to use in the study of institutionalized science?

Are papers cited in the same note/footnote more closely associated than the others?

Are citations truly transitive, i.e. if A cites B and B cites C, then has A really indirectly cited C? If A were queried about it would he really acknowledge all of them? If not, which ones would he acknowledge? Can they be distinguished by "objective" means? Many historiographic studies are based on the assumption of transitivity.

Bibliometrics as a research area and technique has provided results that have given additional understanding of the form, structure and volume of scientific communication. Bibliometric methods have been accepted as one more tool that gives additional knowledge of the conditions and pattern of scientific activity and research.

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"Current Comments"

Journal Citation Studies.
28. Scandinavian Journals

Number 41 October 11, 1976

The 74 journals covered in this regional analysis are listed in Figure 1. In this study we took 'Scandinavia' in the expanded definition that includes Finland. A few Scandinavian journals covered by the *Science Citation Index®* (*SCI®*) in 1974 don't appear on the list in Figure 1. That's because they appear irregularly at long intervals, and no issues arrived in 1974.

Figure 1 gives for each journal its impact factor, the number of times it was cited in 1974; the number of times its 1972 and 1973 articles were cited in 1974; and the number of articles it published in 1972 and 1973. In Figure 1 the journals are ranked by impact.

There are 37 Danish journals, 28 Swedish, 6 Norwegian, and 3 Finnish journals. Only twelve or so of the journals have titles that are not English or title-Latin, and two of them are French. But neither the famous *Comptes Rendus* of the Carlsberg Laboratories nor the *Journal du Conseil* is in any sense a French-language journal. For all practical purposes the Scandinavians publish in English. This does not mean that they are any less proud or show any less concern for their different languages than, let us say (pointedly), the French.[1] Few if any nations, for example, have actually legislated and relegislated as often as has Norway the grammar, vocabulary, and spelling of its language. Perhaps earlier than other nations, the Scandinavians accepted the facts of life in publication, and took care not to hide their scientific light under vernacular bushels.

The 74 journals listed in Figure 1 constitute 3.0% of the 2443 journals covered by the *SCI* in 1974. They published 6422 articles, about 1.6% of the 400,071 items indexed that year. Of more than 5.245 million references processed in the indexing, the Scandinavian journals accounted for about 2% (103,498). The average number of items cited by the references of each article was about 16, slightly higher than the international average of 13.

The articles published in these journals are neither the whole nor the exclusive product of Scandinavian research. Many Scandinavian authors publish in other journals; and Scandinavian journals publish many articles by scientists in other countries. We know from the *Current Contents®* address listings that are cumulated in ISI's *Who is Publishing In Science®*

Figure 1. Scandinavian Journals indexed by the *Science Citation Index* in 1974. Journals are listed in descending order by impact factor. **A** = impact factor. **B** = total number of times the journal was cited in 1974. **C** = total 1974 citations of articles published by the journal in 1972 and 1973. **D** = total articles published by the journal in 1972 and 1973. (In parentheses after the journal's title is a letter indicating country of origin: *D*enmark, *F*inland, *N*orway, *S*weden).

	A		B	C	D
1.	25.579	Transplantation Revs. (*D*)	1592	972	28
2.	4.957	Scand. J. Immunology (*N*)	632	570	115
3.	3.796	Tissue Antigens (*D*)	657	429	113
4.	2.464	Exp. Hematology (*D*)	145	69	28
5.	2.461	Acta Endocrinologica (*D*)	4909	1383	562
6.	2.204	Acta Physiol. Scand. (*S*)	7922	919	417
7.	2.083	Acta Mathematica (*S*)	675	75	36
8.	1.948	Scand. J. Gastroenterol. (*N*)	1424	526	270
9.	1.917	Scand. J. Clin. Lab. Inv. (*N*)	3699	644	336
10.	1.839	Clin. Genetics (*D*)	434	274	149
11.	1.555	Physiol. Plantarum (*D*)	2617	479	308
12.	1.533	Chemica Scripta/Ark. Kemi (*S*)	1498	210	137
13.	1.506	Acta Pharmacol. Toxicol. (*D*)	1395	250	166
14.	1.505	Physica Scripta (*S*)	698	319	212
15.	1.485	Hereditas (*S*)	1541	291	196
16.	1.463	Acta Paediat. Scand. (*S*)	1336	338	114
17.	1.388	Neurobiology (*D*)	143	93	67
18.	1.372	Acta Crystallogr. A (*D*)	1793	516	376
19.	1.367	Scand. J. Hematol. (*D*)	973	283	207
20.	1.333	CR Trav. Lab. Carlsberg (*D*)	260	20	15
21.	1.329	Acta Crystallogr. B. (*D*)	4520	1838	1383
22.	1.257	J. Periodontal Res. (*D*)	476	142	113
23.	1.226	Internat. J. Pept. Prot. Res. (*D*)	129	114	93
24.	1.167	Acta Allergologica (*D*)	334	84	72
25.	1.124	Acta Med. Scand. (*S*)	3993	508	452
26.	1.069	Acta Derm.-Vener. (*S*)	840	218	204
27.	1.063	Ann. Clin. Res. (*F*)	283	119	112
28.	1.042	Acta Chem. Scand. (*D*)	8803	1192	1144
29.	1.034	Acta Obst. Gyn. Scand. (*S*)	798	154	149
30.	0.935	Acta Pharmaceut. Suecica (*S*)	470	115	123
31.	0.872	Acta Path. Micr. Scand. B. (*D*)	597	260	298
32.	0.803	Acta Neurol. Scand. (*D*)	836	183	228
33.	0.802	Scand. J. Urol. Nephrol. (*S*)	225	89	111
34.	0.778	Ericsson Technics (*S*)	48	7	9

Figure 1. Scandinavian Journals indexed by the *Science Citation Index* (cont.)

	A		B	C	D
35.	0.769	Scand. J. Dental Res. (*D*)	215	110	143
36.	0.750	Dansk Bot. Arkiv (*D*)	43	3	4
37.	0.743	Acta Path. Micr. Scand. A (*D*)	394	208	280
38.	0.738	Acta Chir. Scand (*S*)	1645	206	279
39.	0.692	Tellus (*S*)	843	81	117
40.	0.667	Acta Ophthalmologica (*D*)	735	138	207
41.	0.624	Scand. J. Resp. Dis. (*D*)	289	88	141
42.	0.608	Acta Anaesth. Scand. (*D*)	287	62	102
43.	0.600	Envir. Physiol. Biochem. (*D*)	48	36	60
44.	0.585	Oikos (*D*)	479	93	159
45.	0.578	Acta Radiol. Diagnosis (*S*)	451	96	166
46.	0.563	J. Appl. Crystallogr. (*D*)	553	183	325
47.	0.551	Upsala J. Med. Sci. (*S*)	44	38	69
48.	0.540	Acta Odontol. Scand. (*S*)	538	47	87
49.	0.539	Acta Psychiat. Scand. (*D*)	527	76	141
50.	0.536	Physica Norvegica (*N*)	68	15	28
51.	0.504	Agri Hortique Genetica (*S*)	48	2	5
52.	0.491	Acta Vet. Scand. (*D*)	312	83	169
53.	0.450	Sarsia (*N*)	139	27	60
54.	0.441	Scand. J. Psychol. (*S*)	240	41	93
55.	0.429	Scand. J. Plast. Rec. Surg. (*S*)	88	21	49
56.	0.383	Danish Med. Bull. (*D*)	283	36	94
57.	0.377	Nordisk Vet. Med. (*D*)	311	58	154
58.	0.359	Svensk Papperstidning (*S*)	500	94	262
59.	0.347	Acta Orthopaed. Scand. (*D*)	515	51	147
60.	0.340	J. Conseil (*D*)	295	18	53
61.	0.333	Botaniska Notiser (*S*)	224	29	87
62.	0.297	Ark. Matematik (*S*)	116	11	37
63.	0.271	Acta Radiol. Ther. Phys. (*S*)	169	29	107
64.	0.254	Angiologica (*S*)	113	18	71
65.	0.252	Paperi Puu/Papper Trä (*F*)	109	30	119
66.	0.233	Mathematica Scand. (*D*)	230	31	133
67.	0.207	Ericsson Rev. (*S*)	19	6	29
68.	0.143	Acta Chir. Gyn. Fenn. (*F*)	170	19	133
69.	0.094	Jernkontorets Annaler (*S*)	91	3	32
70.	0.086	Botanisk Tidskrift (*D*)	62	3	35
71.	0.077	Kemisk Tidskrift (*S*)	16	10	130
72.	0.025	Kjemi (*N*)	5	3	122
73.	0.000	Bygningsstatiske Medd. (*D*)	1	0	10
74.	0.000	J. Cutaneous Pathol. (*D*)	2	0	0

that in 1974 at least 8540 articles appeared in the scientific press with Scandinavian first-author addresses.[2] This means that the 6422 articles from Scandinavian journals covered by the *SCI* in 1974 published at most 75% of an apparent Scandinavian research output. That 75% is, however, obviously much too high, since Scandinavian journals include so many articles from scientists outside Scandinavia. For example, on a list of highly cited articles from Scandinavian journals, to be published shortly,[3] about half come from other countries. The two most recently published issues of each of the first five journals on the list in Figure 1 contained in all 113 articles. Only 34 (30%) report research done in Scandinavia. On the basis of these recent issues and of the highly-cited-article list just mentioned, from 30% to 50% of the material in Scandinavian journals can be estimated as of 'foreign' origin. In other words, Scandinavian journals seem essentially international, or even supranational. Except perhaps for subscription agents and acquisitions librarians, I doubt for example that there can be many among their audiences who think of *Acta Endocrinologica* as a *Danish* journal, or of *Acta Mathematica* as *Swedish*.

Thus there should be little surprise in the fact that without the legends it would be difficult to determine just what 'national' groups we're dealing with in Figures 2 and 3. Figure 2 shows the 50 journals most frequently *cited by* the Scandinavian journals. (The figure actually lists 52 titles to compensate for the triple appearance of *Acta Crystallographica*.) Figure 3 shows the 50 journals that most often *cited* the Scandinavian journals. These figures have columns showing the number of references or citations made or received by each journal, the number of references or citations made or received by the Scandinavian group, and the number of self-citations. There are columns for percentages that relate some of these counts to each other. The last column in both figures shows each journal's impact factor.

In 1974 the Scandinavian journals cited 9615 different items a total of 102,980 times. The 50 journals listed in Figure 2 (½% of the total items cited) account for about 34% of the total citations made by the Scandinavian journals in their references (35,140 out of 102,980). The Scandinavian journals *were cited by* 1760 different journals a total of 63,664 times. The 50 journals listed in Figure 3 (2.8% of the total citing journals) account for about 29% of the total citations (18,348 out of 63,664).

Lancet heads the list of cited journals in Figure 2, and signals its make-up. There are a few chemistry and physics journals, but on the whole the list is mainly physiology and medicine, reflecting the primary interest--one cannot say of Scandinavian research--but of that segment of the scientific community that publishes in Scandinavian journals. All the cited journals are English-language.

Figure 2. Journals that were *Cited by* Scandinavian Journals.
Journals are listed in order of their citation *by* the Scandinavian group. **A** = total citations by all journals. **B** = total citations by Scandinavian journals. **C** = self-citations. **D** = **B/A** (Scandinavian citations in terms of total citations). **E** = **C/A** (self-citations in terms of total citations, the self-cit*ed* rate). **F** = **C/B** (self-citations in terms of Scandinavian citations). **G** = impact factor.

Journal	A	B	C	D	E	F	G
1. Lancet	57047	1810	–	4.9	–	–	6.677
2. Acta Crystallogr.	7598	1794	1516	23.6	20.0	84.5	–
3. Acta Chem. Scand.	8803	1705	1210	19.3	13.7	71.1	1.042
4. J. Amer. Chem. Soc.	98995	1528	–	1.5	–	–	4.383
5. Acta Crystallogr. B	4520	1517	1294	33.6	28.6	85.3	1.329
6. Nature	59206	1546	–	2.5	–	–	3.636
7. Acta Physiol. Scand.	7922	1334	822	16.8	10.4	61.6	2.204
8. J. Biol. Chem.	81354	1316	–	1.6	–	–	5.845
9. J. Clin. Invest.	24768	1008	–	4.1	–	–	6.992
10. Science	47505	989	–	2.1	–	–	5.412
11. J. Exp. Med.	20699	906	–	4.4	–	–	11.874
12. New Engl. J. Med.	26726	858	–	3.2	–	–	8.364
13. Scand. J. Clin. Lab. Inv.	3699	832	244	22.5	6.6	29.3	1.917
14. Brit. Med. J.	20748	828	–	4.0	–	–	3.556
15. Acta Med. Scand.	3993	817	392	20.5	9.8	48.0	1.124
16. Biochim. Biophys. Acta	51491	803	–	1.6	–	–	3.120
17. J. Chem. Physics	62041	798	–	1.3	–	–	2.918
18. Acta Crystallogr. A	1795	784	356	43.7	19.9	45.4	1.372
19. J. Physiology (London)	22520	778	–	3.5	–	–	4.495
20. Amer. J. Physiology	21519	735	–	3.4	–	–	2.414
21. J. Immunology	15826	592	–	3.7	–	–	5.112
22. Proc. Nat. Acad. Sci. USA	46917	578	–	1.2	–	–	9.989
23. Gastroenterology	8693	572	–	6.6	–	–	5.394
24. J. Appl. Physiology	8619	535	–	6.2	–	–	1.780
25. J. Amer. Med. Assoc.	17211	551	–	3.1	–	–	3.068
26. Biochem. J.	31563	518	–	1.6	–	–	3.627
27. Circulation	14461	476	–	3.3	–	–	6.834
28. Amer. J. Obstet. Gynecol.	8890	456	–	5.1	–	–	2.100
29. Proc. Soc. Exp. Biol. Med.	18171	449	–	2.5	–	–	1.471
30. Physiol. Plantarum	2617	427	416	16.3	15.9	97.4	1.555
31. Ann. New York Acad. Sci.	14668	423	–	2.9	–	–	1.181
32. Plant Physiology	8855	422	–	4.8	–	–	2.580
33. Scand. J. Gastroenterol.	1424	419	344	29.4	24.2	82.1	1.948
34. Acta Chir. Scand.	1645	415	175	25.1	10.6	42.4	0.738
35. Amer. J. Med.	9779	393	–	4.0	–	–	4.411
36. Physical Review	50828	395	–	0.8	–	–	2.670
37. J. Chem. Soc.	19955	372	–	1.9	–	–	1.870
38. J. Lab. Clin. Med.	8798	369	–	4.2	–	–	2.802
39. Circulation Res.	9082	353	–	3.9	–	–	4.922
40. Blood	7120	338	–	4.7	–	–	4.319
41. Acta Pathol. Microb. Sc	991	329	156	33.2	15.7	47.4	–
42. Biochemistry	27080	329	–	1.2	–	–	4.711
43. J. Pharmacol. Exp. Ther.	13753	325	–	2.4	–	–	3.576
44. Pediatrics	6951	318	–	4.6	–	–	2.502
45. Ann. Internal Med.	10231	317	–	3.1	–	–	4.828
46. J. Pediatrics	7183	309	–	4.3	–	–	2.600
47. J. Clin. Endocr. Metab.	11645	294		2.5	–		5.170
48. Clin. Exp. Immunology	4049	287	–	7.1	–	–	4.425
49. Clin. Chim. Acta	5557	284	–	5.1	–	–	1.669
50. J. Neurochem.	7794	280	–	3.6	–	–	3.535
51. Ann. Surgery	7459	279	–	3.7	–	–	2.129
52. Federation Proc.	13072	278	–	2.1	–	–	0.751

Figure 3. Journals that *Cited* Scandinavian Journals.
Journals are listed in order of their citation *of* the Scandinavian group. **A** = total citations of other journals. **B** = total citations from journals in the Scandinavian group. **C** = self-citations. **D** = B/A (Scandinavian citations in terms of total citations). **E** = C/A (self-citations in terms of total citations, the self-citing rate). **F** = C/B (self-citations in terms of Scandinavian citations). **G** = impact factor.

Journal	A	B	C	D	E	F	G
1. Acta Crystallogr. B	6977	1819	1294	26.1	18.5	71.1	1.329
2. Acta Chem. Scand.	6431	1497	1210	23.3	18.8	80.8	1.042
3. Acta Physiol. Scand.	5629	1029	822	18.3	14.6	79.9	2.204
4. Acta Med. Scand.	5319	657	392	12.4	7.4	59.7	1.124
5. Scand. J. Gastroenterol.	3005	578	344	19.2	11.4	59.5	1.948
6. J. Amer. Chem. Soc.	46267	570	–	1.2	–	–	4.385
7. Acta Crystallogr. A	1722	500	356	29.0	20.7	71.2	1.572
8. Scand. J. Clin. Lab. Inv.	3077	477	244	15.5	7.9	51.2	1.917
9. Brain Res.	19626	468	–	2.4	–	–	5.104
10. Physiol. Plantarum	3619	437	416	12.1	11.5	95.2	1.555
11. Biochim. Biophys. Acta	45566	424	–	0.9	–	–	3.120
12. Lancet	19020	375	–	2.0	–	–	6.677
13. Inorganic Chem.	15048	372	–	2.5	–	–	2.457
14. Coord. Chem. Rev.	4588	339	–	7.4	–	–	5.750
15. Nature	26016	339	–	1.3	–	–	3.636
16. J. Immunology	13041	328	–	2.5	–	–	5.112
17. Chem. Scripta	1480	298	85	20.1	5.7	28.5	1.535
18. J. Chem. Soc. Perkin	20327	291	–	1.4	–	–	1.348
19. Scand. J. Haematology	2228	291	127	13.1	5.7	43.6	1.367
20. Amer. J. Physiology	11522*	290	–	2.5	–	–	2.414
21. Acta Path. Microb. Scand B	2257	279	177	12.4	7.8	63.4	0.872
22. J. Chem. Soc. Dalton	10505	277	–	2.6	–	–	2.512
23. Acta Chir. Scand	1952	270	175	13.8	9.0	64.8	0.738
24. Analytical Chem.	27658	269	–	1.0	–	–	3.291
25. Acta Paediat. Scand.	2924	258	150	8.8	5.1	58.1	1.465
26. J. Physiology (London)	10406	258	–	2.5	–	–	4.495
27. Scand. J. Immunology	2145	255	123	11.9	5.7	48.2	4.957
28. Duet. Med. Wschr.	11622	251	–	2.2	–	–	1.017
29. Acta Neurol. Scand.	2088	246	116	11.8	5.6	47.2	0.803
30. Gut	4353	246	–	5.7	–	–	3.336
31. J. Clin. Invest.	10979	243	–	2.2	–	–	6.992
32. Gastroenterology	7771	239	–	3.1	–	–	5.394
33. Hereditas	1692	237	211	14.0	12.5	89.0	1.485
34. Acta Obstet. Gyn. Scand.	1909	236	130	12.4	6.8	55.1	1.034
35. Acta Ophthalmol.	1562	236	193	15.1	12.4	81.8	0.667
36. Acta Pharmacol. Tox.	1470	235	113	15.9	7.7	48.5	1.506
37. Thromb. Res.	2718	232	–	8.5	–	–	2.513
38. J. Exp. Med.	6664	228	–	3.4	–	–	11.874
39. Tetrahedron	13059	223	–	1.7	–	–	1.576
40. Thromb. Diath. Haemorrh.	4933	216	–	4.4	–	–	1.064
41. J. Inorg. Nucl. Chem.	2026	215	–	10.6	–	–	0.962
42. Biochemistry	24565	212	–	0.9	–	–	4.711
43. Brit. Med. J.	12458	207	–	1.7	–	–	3.556
44. Eur. J. Immunology	4002	207	–	5.2	–	–	4.852
45. J. Appl. Crystallogr.	1380	204	113	14.8	8.2	55.4	0.565
46. Cell Immunology	5674	200	–	3.5	–	–	4.848
47. J. Organomet. Chem.	22699	200	–	0.9	–	–	2.392
48. J. Biol. Chem.	33749	198	–	0.6	–	–	5.843
49. J. Pharmacol. Exp. Ther.	7277	198	–	2.7	–	–	3.576
50. Canad. J. Chem.	12685	196	–	1.5	–	–	1.396

Of the 50 journals most cited by Scandinavian journals 11 are from the Scandinavian group. But I find nothing significant in that beyond the fact that they are highly cited journals. Except for the prominence of *Acta Crystallographica*, their order on the list is roughly the same as on the list of all journals ranked by times cited in *Journal Citation Reports*® .4

Figure 3 lists journals that *cited* the Scandinavian journals most. Among these 50, there is the same emphasis on biomedicine that we've seen in Figure 2, but the citing journals include a larger number of chemistry journals. The concentration of Scandinavian journals in Figure 3 follows the general pattern of earlier regional studies. Eight of the top ten that cite the Scandinavians most heavily are Scandinavian, with another twelve scattered down the list. It is interesting to note that the self-citing rate of these Scandinavian journals is unusually low. Only one achieves the average of 20%.

It is important to note the high impact factors of the citing journals in Figure 3. In six cases the impact is less than 1.000, but a good portion of the rest fall between 2.000 and 6.000. It is interesting to compare the impacts here with those on the citing lists from previous regional studies. Here the average of the citing journals' impacts is 2.830. That's the highest we've seen. In the case of the citing journals in previous studies of French, Japanese, German, and Australian/New Zealand journals, the corresponding averages were respectively 1.155, 1.807, 2.336, and 1.573. In other words, the Scandinavian literature seems to be most cited by a group of journals that are *as a group* more significant than the journals that *as a group* most cite the other regional literatures we've studied.

Thus the authorship of the articles published by these journals, as well as their heavy citation by journals that are themselves heavily cited, both attest the basic internationalism of the Scandinavian publications.

This is the sixth in a series of studies of journals published in different countries and geographic areas. As in the other cases, this study will be supplemented by a list of highly cited articles from Scandinavian journals.

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"Current Comments"

Highly Cited Articles. 29. Articles from Scandinavian Journals.

Number 42 October 18, 1976

Here is a list of the fifty most cited articles from Scandinavian journals. The list presents a number of surprises. The first is the number of citations received by the articles. In most of our 'regional' lists of highly cited articles, the least cited on the list has rarely been cited more than 200 times. The last article on this list (number 50 by Kofoed-Johnsen and Ussing) received almost 300 citations.

As with our previous lists, only a few journals are involved--in this case only ten. The journals are listed in Figure 1. Two of them published two-thirds of the articles: *Acta Crystallographica* 21, and *Acta Physiologica Scandinavica* 12. Half of the journals are medical; the other half are about evenly divided between chemistry and physics.

Only twenty-three of the articles report work done in Scandinavia. The rest come from around the world, most of them (16) from the United States. In our previous studies of regional journals and their highly cited articles, there have always been a number from scientists outside the region, but not to this extent. The list confirms the international character of Scandinavian journals demonstrated in a previous journal citation analysis.[1]

Exactly half the articles report medical research, a higher proportion than usually found in lists of this type. Nineteen of the articles deal with physics, most of them from *Acta Crystallographica*.

The two oldest articles (numbers 22 and 47) were published in 1948. They describe methods for biochemical analysis that have been widely used or adapted for wide use. The two are Ouchterlony's "*In vitro* method for testing the toxin production capacity of diphtheria bacteria," and Blix's "Determination of hexoseamines according to Elson and Morgan." In all there are four articles from the 1940s, twenty from the 50s, twenty-five from the 60s and one from 1971. This last is a paper by Germain *et al.* (number 35) on "The application of phase relationships to complex structures. It is the third of a series ("3. The optimum use of phase relationships.") The first two articles in the series weren't cited often enough in the period 1961-1975 to make this list of fifty articles. However, all the three parts have been cited a total of 732 times. The same situation probably holds for other articles on the list that are parts of series (numbers 10, 16, 27, and 45).

The articles are listed in Figure 2 in decreasing order of their total citations.

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Figure 1. Sources of the most frequently cited articles published in Scandinavian journals. A = number of articles on the list in Figure 2. B = journal title (titles in parentheses are present titles whose counts have been combined with those for former titles in impact calculation, etc.). C = total citations in 1974. D = total citations of 1972 and 1973 articles in 1974. E = number of articles published by journal in 1972 and 1973. F = impact.

A	B	C	D	E	F
21	Acta Crystallographica	13111	2394	1759	1.361
12	Acta Physiol. Scand.	7922	919	417	2.204
4	Acta Chem. Scand.	8803	1192	1144	1.042
3	Acta Pathol. Microb. Scand.	991	468	578	0.809
3	Scand. J. Lab. Clin. Invest.	3659	644	336	1.917
2	Physiol. Plantarum	2617	479	308	1.555
2	Transplantation Rev.	1592	972	38	25.579
1	Acta Radiologica (Diagn. & Ther.)	1802	187	273	1 460
1	Arkiv Kemi (Chemica Scripta)	1498	210	157	1.553
1	Mat. Fys. Medd. KDVS	105	–	–	–

Figure 2. Highly cited articles from Scandinavian journals.
A = item number. B = times cited 1961-1975.

A	B	Bibliographical Data
1.	1780	**Cromer D T & Waber J T.** Scattering factors computed from relativistic Dirac-Slater wave functions. *Acta Crystallogr.* 18:104-9, 1965. [*Los Alamos Scientific Lab., Los Alamos, New Mexico*]
2.	1495	**Cromer D T.** Anomalous dispersion corrections computed from self-consistent field relativistic Dirac-Slater wave functions. *Acta Crystallogr.* 18:17-23, 1965. [*Los Alamos Scientific Lab., Los Alamos, New Mexico*]
3.	1138	**Seldinger S I.** Catheter replacement of the needle in percutaneous arteriography: a new technique. *Acta Radiologica* 39:368-76, 1953. [*Roentgen Diagnostic Dept., Karolinska Inst. Stockholm*]
4.	1079	**Hanson H P, Herman F, Lea J D & Skillman S.** HFS atomic scattering factors. *Acta Crystallogr.* 17:1040-44, 1964. [*Univ. of Texas, Austin*]
5.	945	**Karle J & Karle I L.** The symbolic addition procedure for phase determination for centrosymmetric and noncentrosymmetric crystals. *Acta Crystallogr.* 21:849-59, 1966. [*U.S. Naval Res. Lab., Wash. D.C.*]
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